Oil & Grease Removal Using Human Hair Waste (HHW)

By

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(10302)

Dissertation submitted in partial fulfillment of the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

(Assoc Prof Dr. Shamsul Rahman Mohamed Kutty)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH,PERAK

JANUARY 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NURNATASHA BINTI AYUB ZAMRI

ABSTRACT

'Oil and Grease Removal Using Human Hair Waste (HHW)'. Oil and grease can give serious impact towards environment like anoxic water, which cause damage to the aquatic life due to depleting in oxygen content in water. The objective of this research was to determine the feasibility of human hair waste (HHW) to remove oil and grease from oil refinery wastewater. HHW was collected from hair saloon at Pusing, Perak while the wastewater was collected from oil refinery at Kerteh, Terengganu. The effect of various dosages of HHW and contact time on removal of oil and grease from oil refinery wastewater were evaluated by batch studies. 100 mL of prepared wastewater sample was filled into conical flasks. HHW was added into each conical flask at various dosages ranging from 10000 mg/L – 50000 mg/L. The samples were then agitated using the orbital shaker at various contact times of 3, 6, 9, 12, 15, 18, 21, 24, 48, 72, 96 and 120 hours. After end of each contact time, those samples were filtered and test for oil and grease concentration. The highest oil and grease removal of 78 % was achieved at 30000 mg/L dosage of HHW at 24 hours contact time, while the maximum removal was achieved by 71 % with 50000 mg/L dosage of HHW at 21 hours of contact time. The adsorption isotherm yield by HHW is Freundlich isotherm and Pseudo second order kinetic model HHW proved to be feasible in removing oil and grease.

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....In the name of ALLAH, the most merciful and gracious...

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May ALLAH bless all our jobs, deeds and cooperation in achieving success in our life.

-Thank You-

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Oil and grease can cause severely damage to the environment once they are released and one of the industrial that produces these entire things is the oil refinery industry. This Final Year Project will highlight on the feasibility of using human hair waste (HHW) as a sorbent of oil and grease from oil refinery wastewater. As human hair is natural and easy to get, it will be economical to use it as one of oil and grease removal material.

Human hair is the outer part or the external coating of mammal life where most of people did not realize the use of it especially after it turned into human waste. Human hair has several components that are proteins, water, lipid pigments and other components where the hair fibre is composed by 3 main structures that are cuticle, cortex and medulla. (Velasco, et.al. Jan 2009). The cuticle part has lipid bond which provide the hydrophobic characteristic that is need as oil sorbent.

Human hair that will be used in this study is from the hair salon where people get their hair services like cutting and style the hair. This study will include the capacity of oil adsorption by hair and the amount of oil and grease removal from the wastewater. The parameter that are used in order to find the feasibility of human hair waste as oil and grease remover are dosages of human hair waste (HHW) and the contact time. In order to find the efficiency of HHW to remove oil and grease, the initial concentration of oil and grease are measured in unit mg/L. Besides, the adsorption of oil and grease by HHW will be analyzed using statistic analysis, isotherms and kinetics study.

1.2 PROBLEM STATEMENT

Oil and grease can give serious impact towards environment like anoxic water, which cause damage to the aquatic life due to depleting in oxygen content in water. This happen because, oil and grease has lower densities compared to water and not mixes well together which will create an immiscible film at the water surface. This film will inhibit the dissolving oxygen and reduce the dissolving oxygen capacity in water which leads to environmental problems.

Oil and grease will pollute the environment and effect the surrounding like river pollution, aquatic life destroyed and if the oil and grease become entrapped in sludge particles the density of the sludge can be affected and it may tend to float in the clarifier rather than settling, so there are likely to be issues with high levels of suspended solids in the discharge. According to Malaysian Sewage Industrial Effluent Quality Standard, the standard A for oil and grease concentration is 0 mg/L while for standard B is 10 mg/L

Besides, there is abundance of human hair waste from saloon that just being thrown without any used of it. By study the feasibility of human hair waste as oil and grease remover may likely reduced cost in removing oil and grease from wastewater because human hair waste is free and easy to get it.

By using human hair waste, it will help to cater the pollution problem that caused by oil and grease besides we are not wasting the energy to get rid of those hairs instead we are reusing it into a biodegradable product that is environmental friendly.

1.3 OBJECTIVES

The main objectives of this research are:

1) To determine the feasibility and efficiency of human hair waste to remove oil and grease from oil refinery wastewater.
2) To use human hair waste as useful product.

1.4 SCOPE OF STUDY

This study is to determine the feasibility of human hair waste to remove oil and grease from oil refinery wastewater. There will be 3 stages of works that involve in this project that are **sample collection, sample preparation and laboratory test.** The lists of test in laboratory will be conducted for this project:

I. Oil & grease analysis (removal capacity)

In this study, the following parameters are considered:

I. Amount of hair (varies from 1000 mg to 5000 mg)
II. Oil refinery wastewater volume (100 mL)
III. Contact time (Varies from 3 hours to 24 hours with interval time of 3 hours)

The parameters that are used to measure for batch study are dosage of human hair waste (HHW), oil refinery wastewater volume and contact time. From that, we can determine how efficient human hair being used as oil and grease remover.

After all the experimental work are done, all data from the results will be analyzed using statistic analysis, isotherms and kinetics studies in order to find the efficiency of HHW in oil and grease removal according to the variety of parameters and type of adsorption it is occupied.

CHAPTER 2

LITERATURE REVIEW

2.1 MATERIAL & CHARACTERISTIC

Generally, wastewater containing oil and grease especially petroleum and refined oil can cause severe damage towards environment due to their characteristic of lower densities make them cannot mix well with water therefore make immiscible film on the water surface that will inhibit dissolving oxygen in water and reduce dissolving capacity of oxygen in water, resulted in serious environmental problem. Oil refinery wastewater basically consists of suspended, dispersed, emulsified and etc. (Li, 14 Sept,1993) – refer Figure 2.1

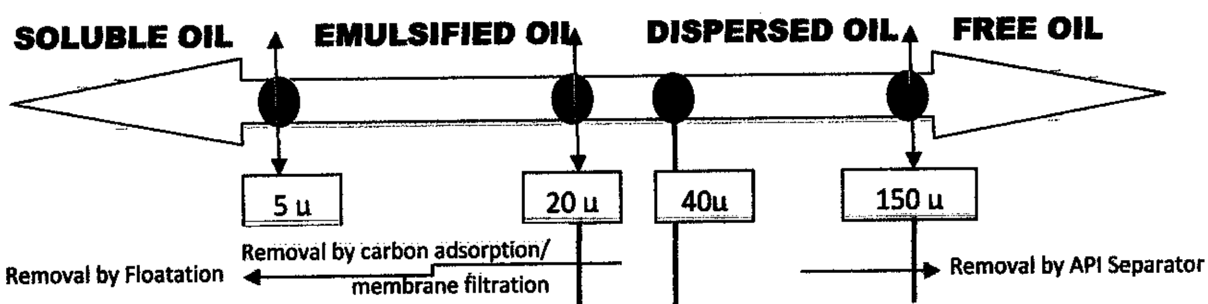


Figure 2.1: Classification and Size Range of Oil Droplet (micron)

For the oil adsorption studies, there many researchers already find out the material for oil adsorption purposed but most of them are for oil spill cleanup at sea like using Butyl rubber (Ceylan et. Al., 2009), nonliving biomass (Salvania sp) (Ribeiro et.al, 2000), rice straw (Feng Sun et.al.,2002), milkweed (type of plant) and cotton fibre (Choi & M.Cloud, 1992). All of these materials are invented and used for oil adsorption due to the hydrophobicity characteristic and can be classified into natural (non-living biomass, rice straw, milkweed, human hair) and human made sorbent (Butyl rubber, cotton fibre) which my project will used natural sorbent that is human hair.

Hydrophobicity, the surface area and the capillary of sorbents are the major determining factors when choosing the best sorbent for oils and other hydrocarbons. (Ribeiro et.al., 2000). Other than that, the reusability and biodegradability of the material also the main concern even though it is good as oil sorbent, easy to produced and reused like synthetic polyurethanes and expanded polypropylene due to its long-term stability after use causing the disposal problem. (Ribeiro et.al, 2000). High uptake capacity and high rate of uptake, buoyancy and retention time also the main properties that need take care off like Butyl Rubber did (Ceylan et. al., 2009). Hair also has the hydrophobic, buoyancy and the surface area properties that make it as good oil sorbent. Besides it is also easy to find, low cost and biodegradable make it as an ideal material to be used in oil and grease removal from oil refinery waste water.

There is several of oil sorbent appearance has been researched like Butyl Rubber is produced in cylindrical tissues of about 14 cm diameter where actually the butyl rubber is come from tire industry for the preparation of inner tubes and inner line (Ceylan et. al., 2009). This Butyl Rubber study is use for oil clean up from surface water due to its hydrophobicity; fast-responsivity and reusability where it is can be squeeze up after use and then can be reused for next oil adsorption (Ceylan et. al., 2009).

Some of the sorbent was grinding become in powdered form like the nonliving biomass (Salvania sp.) study. The sample with varied size (about 1 gram) was placed in a 100 mL of oil in a beaker then put in shaker/ agitator for several amount of time. The same method also applied here as the oil adsorption capacity is determined by weighing the weight of sample before and after the test (Ribeiro et. al., 2000). Besides, it can be done in two different situation like oil with water (for my case, oil and wastewater) and also in the absence of water (M.Radetic et. al., 2003). The study showed that the oil sorbent in general having two mechanisms that are absorption and adsorption

There is an invention oil and grease treatment from oil refinery using spinnel ferrite powder that had been patterned by US Pattern. (Li, 14 Sept,1993) The ferrite powder is added to wastewater for adsorbing the oil and grease contains in wastewater and then separated by external magnetic field. The parameters that took into consideration are pH, dosage of ferrite powder, contact time and temperature. The result is shown that the adsorption amount of oil and grease per % of the spinel ferrite decreases with respect to the increase of addition amount of spinel ferrites. For pH study, the spinel ferrite does not influenced by different pH values range from 2 to 13 and for temperature it shows that the spinel ferrite powder is suitable to treat wastewater containing oil and grease at the temperature of below 100 °C.

The parameters that might affect oil and grease removal are like pH, temperature, contact time and dosage. The suitable pH for oil and grease removal is range between 4 to 9 (Qingjie & Xiaohui, 2008). While the other parameters like contact time and dosages of HHW will be examined in this study in order to determine the efficiency of HHW in removing oil and grease from oil refinery wastewater.

Most of the research will use the previous invention to find the feasibility of HHW as a new oil sorbent invention. Other than the oil adsorption removal test, the physical look also will be examined in order to see the structure of the sample before and after the oil sorbent.

2.2 ADSORPTION ISOTHERMS STUDIES

Adsorption isotherm is mathematical equation that show the relation between adsorbate and the amount of it can adsorb per mass. Adsorption is usually used in removal of contaminants from removal like hardness, heavy metals, colours, oil and grease and so on. This adsorption isotherms study needs an equilibrium adsorption where the equilibrium state is established when the amount of solute is adsorbed onto the adsorbent is equal to the amount of being desorbed (Donmez et.al.,1999).

This project wills employed by these two adsorption isotherms that are Langmuir and Freundlich Isotherms.

2.2.1 Langmuir Isotherm

The Langmuir isotherms theory assumed that the adsorbate has monolayer coverage over a homogenous adsorbent surface (Langmuir, 1918);(Donmez et.al., 1999). At equilibrium state, the adsorption cannot occur anymore because it is reached the saturation point. Once the oil and grease is occupied the HHW, no adsorption can take place at that site. The equations representing the isotherm and the corresponding rearranged forms to obtain linear plot are as follows:

$$q_e = \frac{x}{m} = \frac{bQ_0C_e}{1+bC_e} \tag{2.1}$$

$$\frac{C_e}{q_e} = \frac{1}{Q_0b} + \frac{1}{Q_0}C_e \tag{2.2}$$

Where,

q_e	=	amount of solute adsorbed at equilibrium per unit weight of adsorbent (mg/g)
x	=	mass of material adsorbed (mg)
m	=	mass of adsorbent (mg)
C_e	=	concentration of adsorbate in solution after adsorption is complete (mg/l)
Q_0b	=	constants

In order to get the equation, $\frac{C_e}{q_e}$ will be plotted against C_e and the linear line are plotted. By comparing the linear equation, y= mx+c with eq (2.2), the constant values can be obtained. Q_0 is the maximum amount of oil and grease per unit weight to form a complete monolayer on the surfaces of adsorbent. While b is representing a constant related to the affinity of the binding sites and Q_0 represents adsorption capacity limits when HHW surface is fully covered by oil and grease (Donmez et.al., 1999).

The Langmuir equation is applicable to monolayer or homogenous adsorption where each molecule has equal energy of adsorption (Allen, et.al, 2003).

2.2.2 Freundlich Isotherm

Freundlich Isotherm assumes that as the adsorbate concentration increases, the concentration of adsorbate on the adsorbent surface also increases. Theoretically, using this expression, an infinite amount of adsorption can occur (Freundlich, 1906). Besides, The Freundlich modeling comprehends the heterogeneity of the adsorbent's surface, their energies and exponential distribution sites (Isa et.al, 2008). The equation that represents this isotherm is:

$$q_e = \frac{x}{m} = K_f \, C_e^{\frac{1}{n}} \tag{2.3}$$

$$\ln q_e = \ln K_f + \frac{1}{n} \ln C_e \tag{2.4}$$

Where,

q_e	=	amount of solute adsorbed at equilibrium per unit weight of adsorbent (mg/g)
x	=	mass of material adsorbed (mg)
m	=	mass of adsorbent (mg)
C_e	=	concentration of adsorbate in solution after adsorption is complete (mg/l)
K_f, n	=	constants

By plotting graph $\ln q_e$ against $\ln C_e$, a linear line of Freundlich equation can be obtained by comparing $y = mx + c$ and $\ln q_e = \ln K_f + \frac{1}{n}\ln C_e$.

K_f is a constant that represent adsorption capacity while n is adsorption intensity indicators.

Both isotherms will be employed in this study in order to find which isotherm will fit this oil and grease adsorption by HHW.

2.3 KINETIC STUDIES

Kinetic studies are used to clarify the mechanism of a solute sorption from aqueous solution onto adsorbent and also to show adsorbent's uptake rate and this rate is controlling the residence time of adsorbate at the solid liquid interface. (Augustine et.al., 2007) There are two kinetic models that will employed in this study that are pseudo first order and pseudo second order.

2.3.1 Pseudo -First Order

Pseudo- first order kinetic model are based on solid capacity (Acemioglu, 2005). The models and their linear form can be expressed as follows (Ho and McKay, 1998):

$$\frac{dq}{dt} = k_1\,(q_e - q) \qquad (2.5)$$

$$\ln(q_e - q) = lnq_e - k_1 t \qquad (2.6)$$

Where,

q_e = the amount of solute adsorbed at equilibrium per unit weight of adsorbent (mg/g)

q = the amount of solute adsorbed at time t per unit weight of adsorbent (mg/g)

k_1 = constant

By plotting $\ln(q_e - q)$ against time, t, it will give a linear relationship where k_1 and q_e can be determined from the slope and intercept of linear equation y = mx + c.

2.3.2 Pseudo -Second Order

The Pseudo-second order kinetic model is based on solid phase sorption (Acemioglu, 2005). The models and linear form can be expressed by (Ho and McKay, 1998):

$$\frac{dq}{dt} = k_2\,(q_e - q)^2 \qquad (2.7)$$

$$\frac{t}{q} = \frac{1}{k_2\, q_e{}^2} + \frac{t}{q_2} \qquad (2.8)$$

Where,

q_e = the amount of solute adsorbed at equilibrium per unit weight of adsorbent (mg/g)

q = the amount of solute adsorbed at time t per unit weight of adsorbent (mg/g)

k_2 = constant

By plotting $\ln(q_e - q)$ against time, t, it will give a linear relationship. The k_2 value, can be determined by comparing equation (2.8) with linear equation that is y= mx+c.

CHAPTER 3

METHODOLOGY

3.1 PROJECT IDENTIFICATION

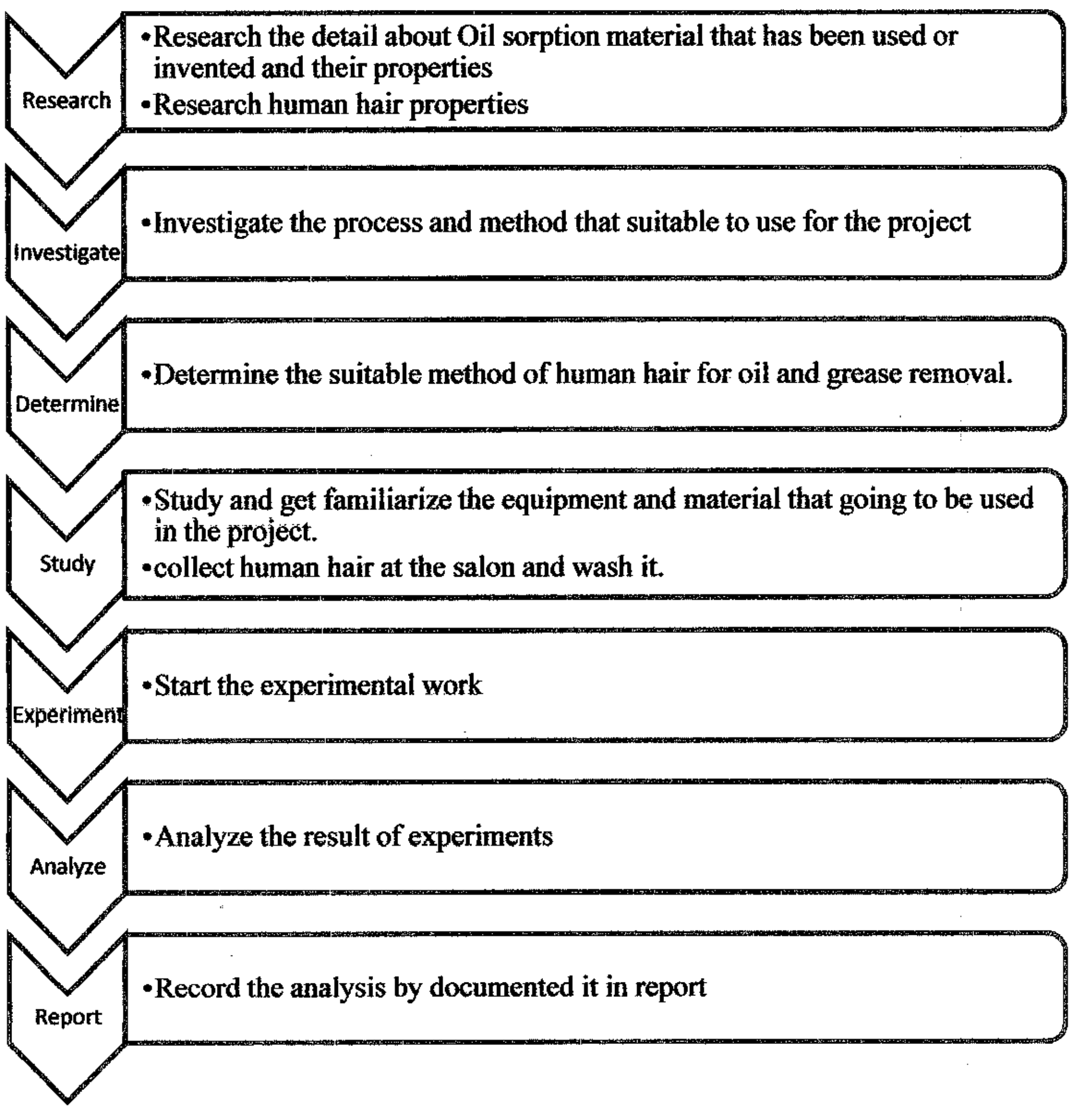


Figure 3.1: Progress Flow Chart (Refer Appendix B)

3.1.1 Sample Collection.

The material that is used as oil sorbent is human hair where the hair is collected at hair salon at Pusing, Perak. While for the waste water from oil refinery was taken by an graduate assistant, Mr. Megat at oil refinery in Kerteh,Terengganu using sterile plastic container. Those wastewater samples were kept in cold room.

3.1.2 Sample Preparation.

The human hair that has been collected was then cleaned by sort out the debris and all unnecessary particles from the conglomeration of hair and cleaned all those oily hair with shampoo. The washes were done by 3 times so that all the human hair is put in the same state condition (not in oily condition and normal state of hair). After that all the water is drained out and put in a tray for drying purposed. The tray is covered by aluminium foil so that the sample not contaminated by other particles. The human hair sample then put in oven for drying purposed at 37° C (human body temperature) for 3 days.

3.2 EXPERIMENTAL WORK

3.2.1 pH Test Procedure

The objective of this test is to determine the pH of human hair waste and oil refinery wastewater. This is because the oil and grease adsorption are efficient at pH 3-9. (Qingjie & Xiaohui, 2008). If both samples are in range of pH 3-9, there is no need pH adjustment before doing the oil and grease adsorption process.Human hair waste's pH is determined by soaked it in distilled water also prepare 1 blank sample and take the pH readings after 24 hours. Take 3 readings and take average in order to reduce human error.

3.2.2 Experimental Procedure for Oil & Grease Removal

The objective of this test is to determine the oil and grease concentration after the oil and grease removal process by HHW. Batch study is conducted in this project with varied the parameters that are dosages of HHW and contact time.

The experiment is done in room temperature (28 ± 1 °C). The HHW sample is prepared by weighing it 1 gram, 2 gram, 3 gram, 4 gram and 5 gram to vary the dosages of HHW. Then put the weighted HHW into 250 ml conical flask that has been labelled accordingly. 100 ml of oil refinery wastewater is measured with measuring cylinder then put into the conical flask that contained measured HHW and prepare a blank sample that is wastewater without HHW. All the samples are prepared and labelled according to different dosages of HHW and different contact time of 24 hours with 3 hours of contact time and extended till, 48 hours, 72 hours, 96 hours and 120 hours with each sample is triplicate. So, with 6 conical flasks with different HHW dosages that are triplicate of each samples times 11 different contact times, in total there are 396 samples that are agitated using an orbital shaker operating at 250 rpm. After reached the desired contact time, the sample is taken out then filtered through Whatman filter paper. pH of the samples is checked and reduce it to less than pH 2. 5mL of Hexane and 50mL of filtered samples is mixed and shake for 2 minutes for oil extraction from the wastewater. There will be 2 layers since hexane is lighter than water, and then take 50μL of upper layer that is hexane and extracted oil using syringe and put it on Infracal TOG/TPH Analyzer (Model HATR-T2). The result of oil and grease concentration (mg/L) will be displayed.

3.2.3 SEM Test

Hair physical structure that will examine is on the how it would look alike before and after oil adsorption using SEM tools. SEM is examining the operation and functioning of ultra-small resonant structures, and specifically using an SEM as the testing device and its electron beam as an exciting source of charged particles to cause the ultra-small resonant structures to resonate and produce EMR.

The test is done by technologist from Mechanical Department due to the limited equipment of SEM tools. The procedure is just to booking the slot on every 1st date of every month at Mechanical Department. All the result of SEM test is given by the lab technologies.

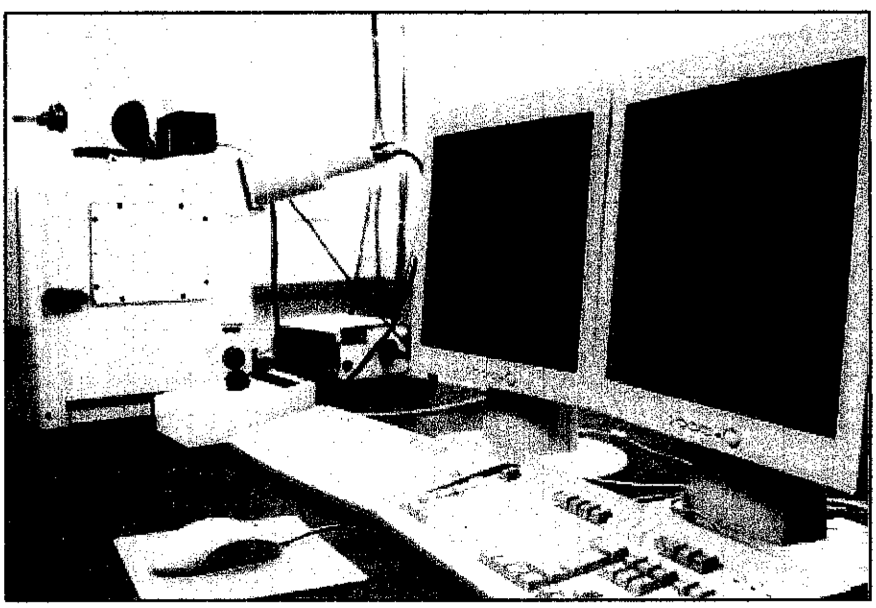


Figure 3.2: SEM Machine

3.3 ECONOMIC BENEFIT

The cost of making this project is:

No.	Experiment	Items	Price (RM)
1	Oil adsorption capacity	3 Column (1 = RM 50)	150.00
		Shampoo (200 mL)	4.90
2	Oil and Grease analyser	Tetrachloroethelyne	165.00
		Total	319.90

The above price was subjected to change due to current price by the supplier.

This project is product based where the human hair will be used as the main material for removal oil and grease in oil refinery wastewater treatment and it is not a priceless because it can get free from any hair cut salon. The above budget will just used for research purposed only.

CHAPTER 4

RESULTS & DISCUSSION

4.1 Results and Discussion

4.1.1 pH Test

From the pH test that has been conducted, pH of human hair waste is 5 to 6 while pH of oil refinery wastewater is 5 to 8. Since the pH for both HHW and oil refinery wastewater are in the range of effective pH for oil and grease removal that is pH 3-9, so there is no adjustment need to be done in this study. (Qingjie & Xiaohui, 2008)

4.1.2 Oil and Grease Removal Test

Parameters: a) Oil refinery wastewater volume (constant = 100 mL)

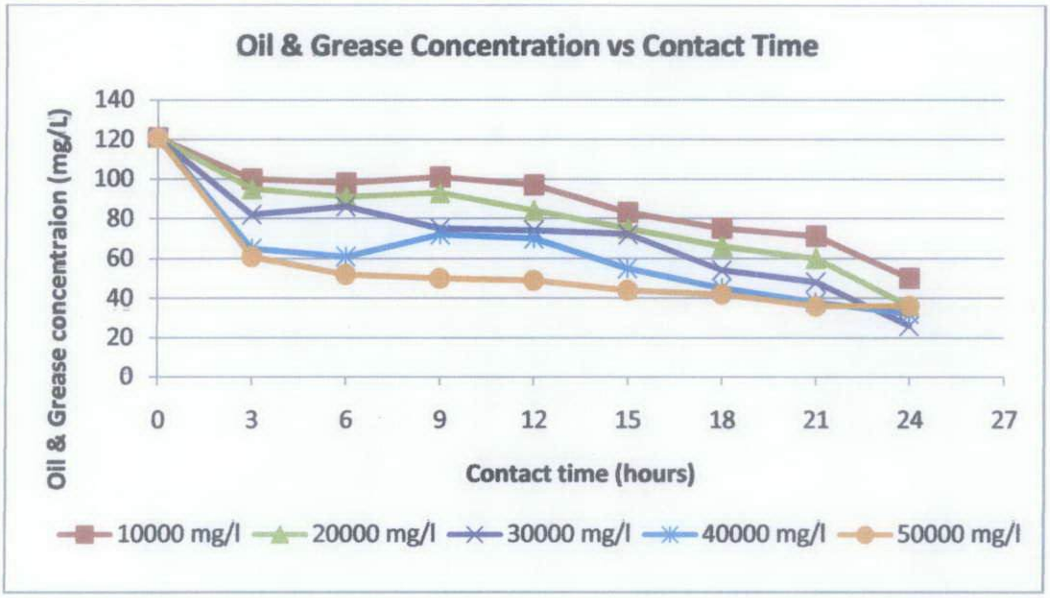
b) Human hair waste dosage (manipulative 10000-50000 mg/L)

c) Contact time (constant = 24 hours with time interval of 3 hours)

Raw sample of oil and grease concentration = 121 mg/L

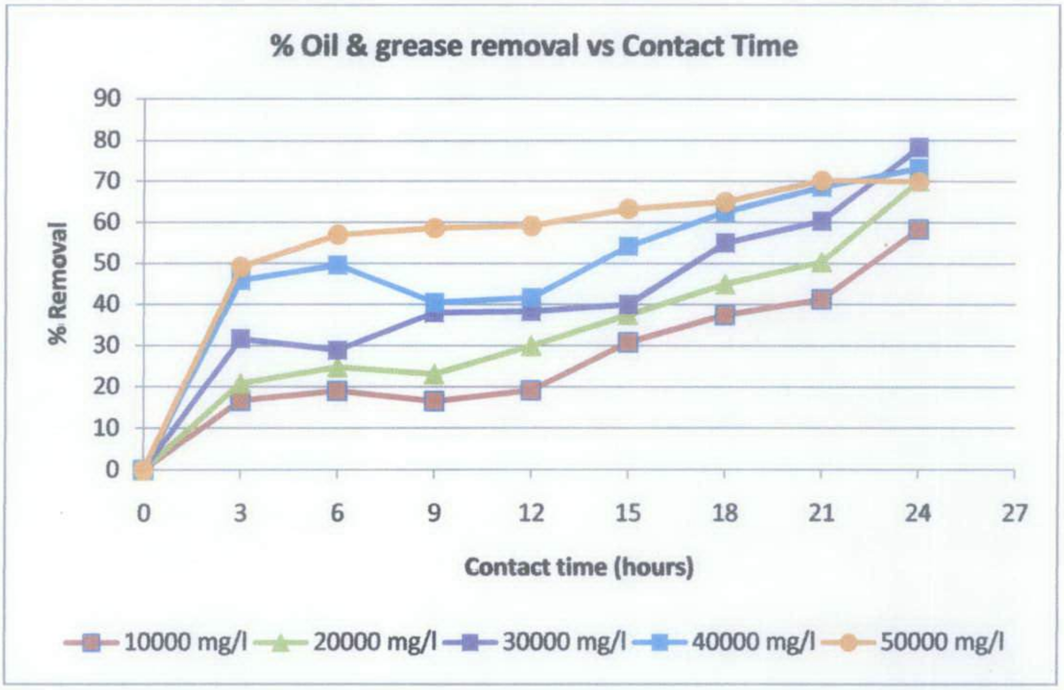
4.1.2.1 Effect of Contact Time

Figure 4.1: Oil & Grease Concentration vs Contact Time



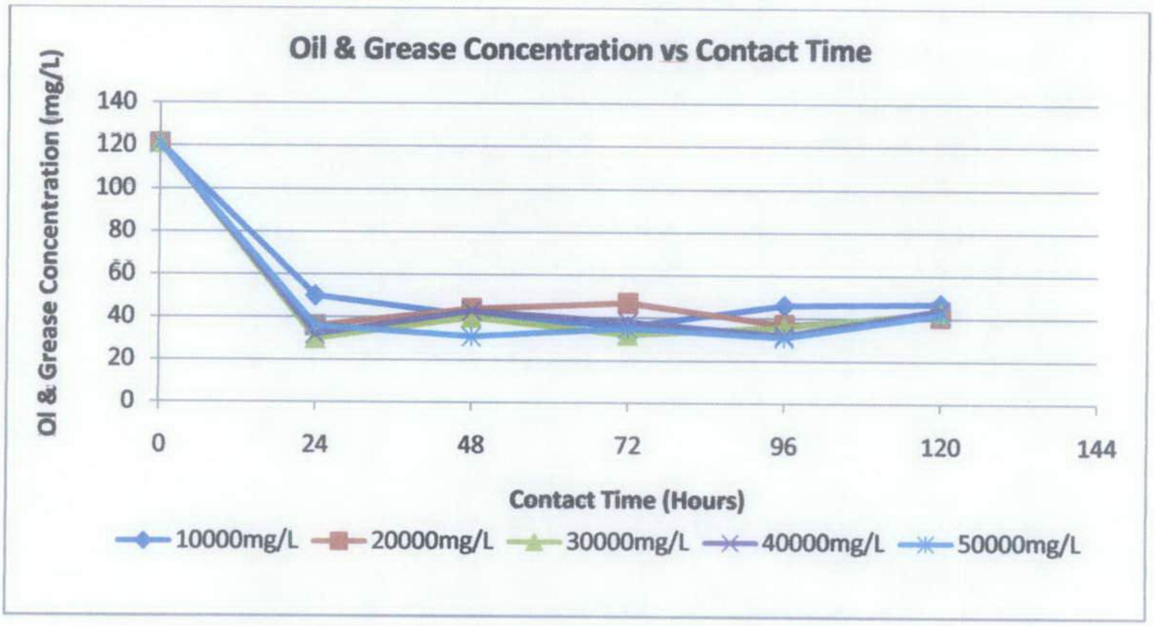
Referring to the figure 4.1, it shows that for the first 3 hours of contact time, the adsorption start to take place. As the dosages increasing, the shorter time it needs to reach equilibrium state. The 50 000 mg/L of HHW dosage is reaching the equilibrium state starting at 21 hours of contact time compared to other dosages that may needs longer time to stable.

Figure 4.2: Oil & Grease Removal Efficiency vs Contact Time



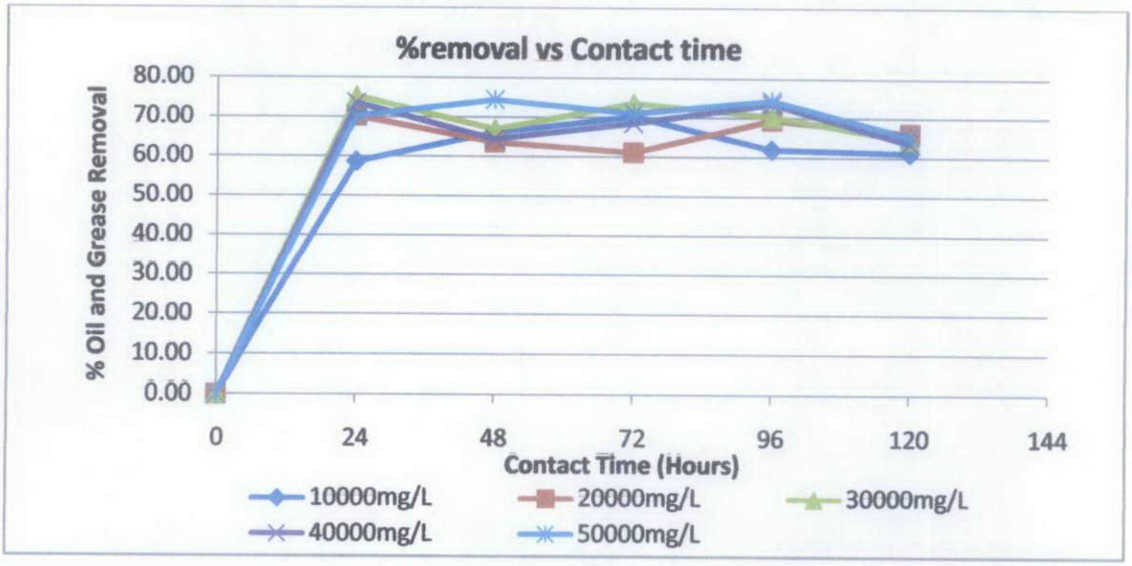
According to figure 4.2, the removal efficiency is gradually increased as the contact increasing. The maximum removal efficiency is reach at 24 hours of contact time with 30 000 mg/L of HHW dosages that is 78 % but it did not reached the equilibrium state. So, in order to determine the equilibrium contact time, the experiment is extended until 120 hours.

Figure 4.1a: Oil & Grease Concentration vs Contact Time



Referring to the above, figure 4.1a is the oil and grease concentration after extended the contact time until 120 hours. It is shown that all the dosages are reached the equilibrium state after 24 hours of contact time.

Figure 4.2a: Oil & Grease Removal Efficiency vs Contact Time



Above figure shows the percentage of oil and grease removal efficiency after extended the contact time where all the dosages are stable after 24 hours of contact time which mean that 24 hours is adequate to take maximum oil and grease adsorption for all dosages. Adequate contact time between adsorbent and adsorbate is needed for adsorption process. According to the statistic analysis that have been done, there no significance difference between any difference in contact time with 95 % of confidence level but there is significance difference between 3 hours and 24 hours contact time with 90% of confidence level

4.1.2.2 Effect of HHW Dosages

Figure 4.3: Oil & Grease Concentration vs HHW Dosages

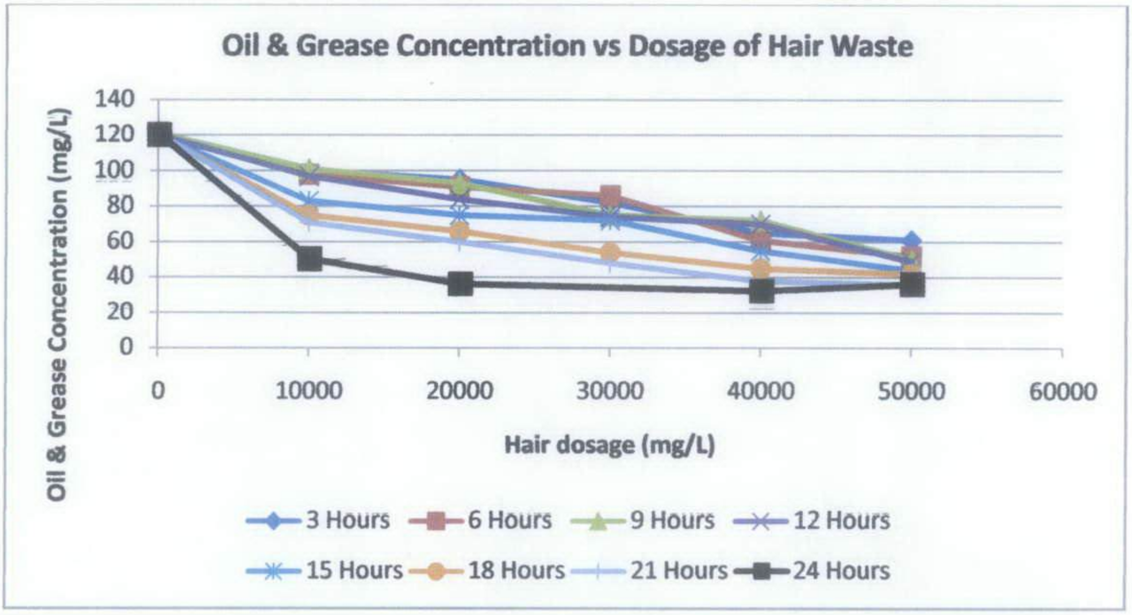


Figure 4.3 above shows the oil and grease concentration after adsorption process with varied dosage of HHW. From the figure, with 24 hours of contact time, with 40 000 mg/L of HHW dosages is adequate to remove oil and grease compared to other contact time.

Figure 4.4: Oil & Grease Removal Efficiency vs HHW Dosages

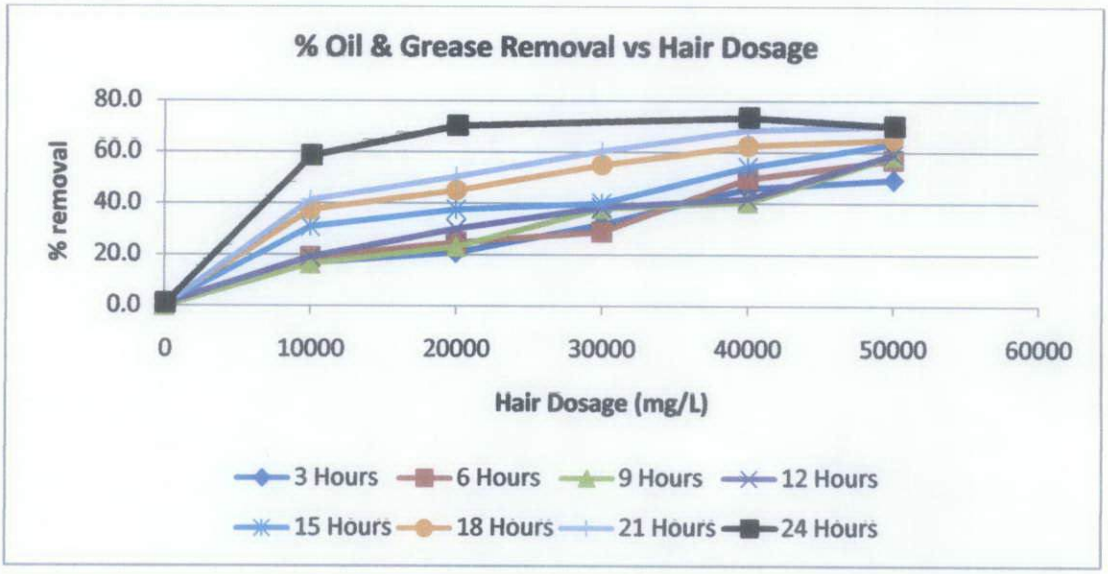
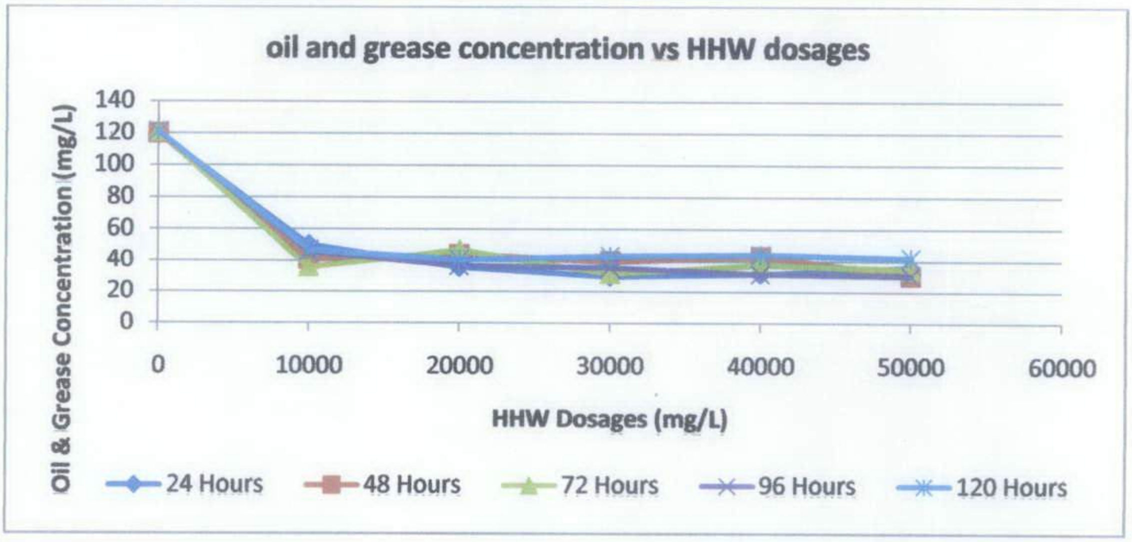


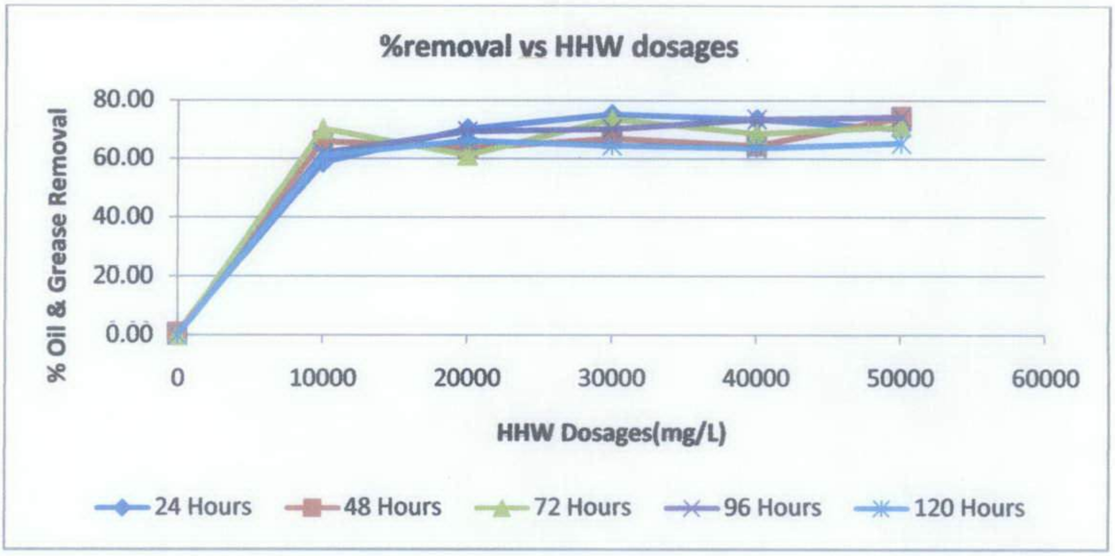
Figure 4.4 is shown the oil and grease removal efficiency after adsorption process where the maximum removal efficiency is 78 % at 40 000 mg/L at 24 hours of contact time. At 24 hours of contact time with 40 000 mg/L of HHW dosage, the adsorption process reach equilibrium state compared to others contact time that need more dosages of HHW. In order to see the equilibrium state, contact time is extended till 120 hours.

Figure 4.3a: Oil & Grease Concentration vs HHW Dosages



Above figure showed the oil and grease concentration after extended contact time until 120 hours which can be seen that with 30 000 mg/L of HHW dosages, it reach the equilibrium state for all.

Figure 4.4a: Oil & Grease Removal Efficiency vs HHW Dosages



Above figure showed the oil and grease removal efficiency for different dosages of HHW after extended the contact time. The maximum removal efficiency is 78 % reach at 30 000 mg/L at 24 hours of contact time The removal reach the equilibrium state with 30 000 mg/L of HHW dosages for all contact time except for 120 hours of contact which reach equilibrium at 20 000 mg/L HHW dosages which means that 30 000 mg/L of HHW dosage is adequate to remove oil and grease. With adequate contact time, the higher the dosages of HHW, the greater amount of oil and grease that can be remove. By using statistic analysis, there is significance difference between 10 000 mg/L with 40 000 mg/L and 50 000 mg/L dosages with 95 % of confidence level.

4.1.2.3 Isotherms Studies

Following is Langmuir isotherms that have been plot from oil and grease concentration after treatment data. The data varies according to contact time that are 24 hours, 48 hours, 72 hours, 96 hours and 120 hours that reach equilibrium state.

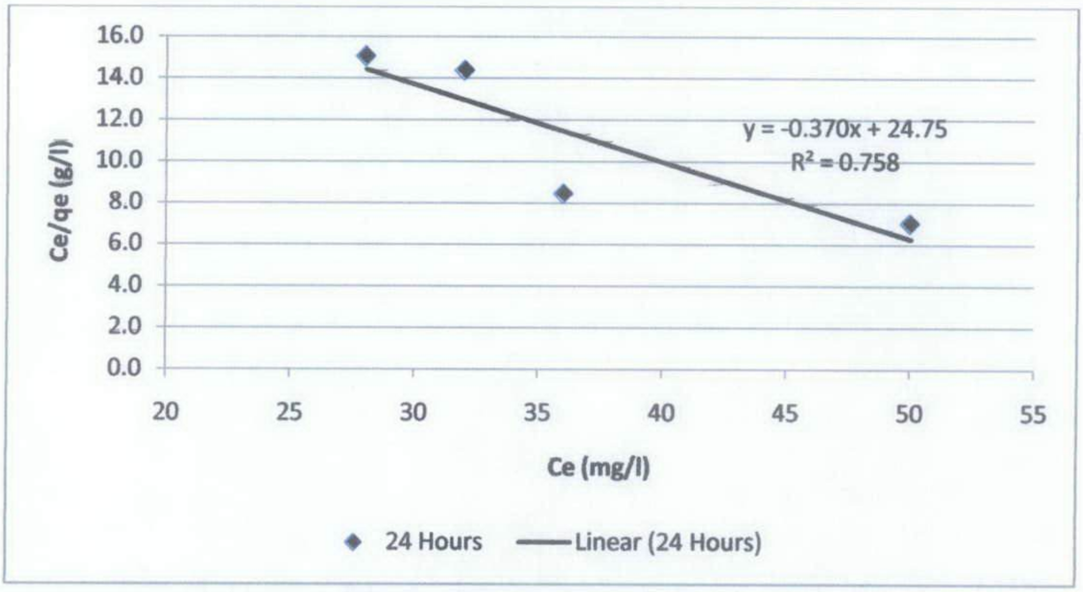


Figure 4.5a: Langmuir isotherm for Oil and Grease adsorption: [Oil grease 121 mg/l, contact time 24 h, volume 100 ml, agitation speed 250 rpm, temperature, 28±1 °C]

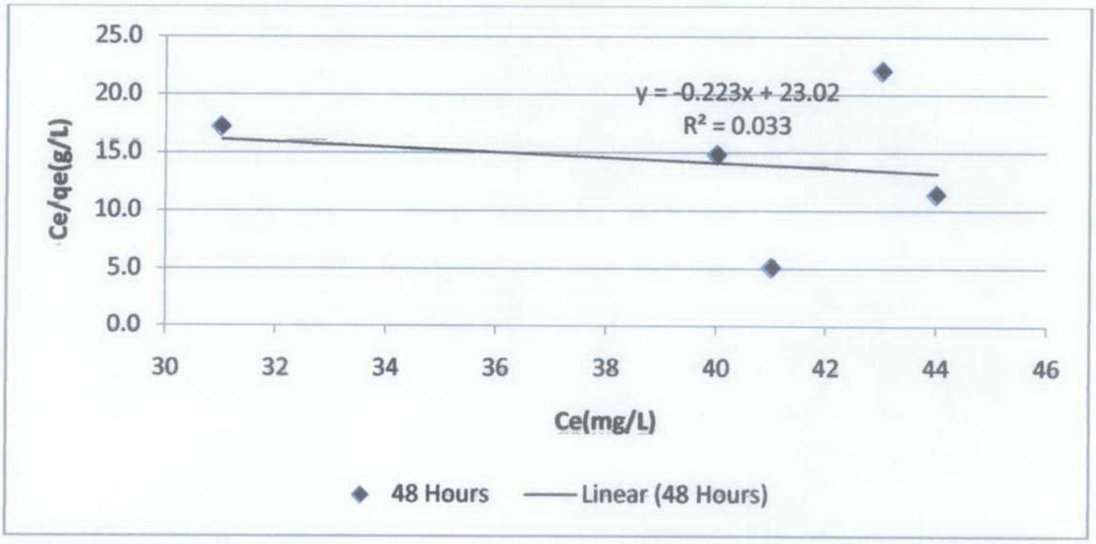


Figure 4.5b: Langmuir isotherm for Oil and Grease adsorption: [Oil grease 121 mg/l, contact time 48 h, volume 100 ml, agitation speed 250 rpm, temperature, 28±1 °C]

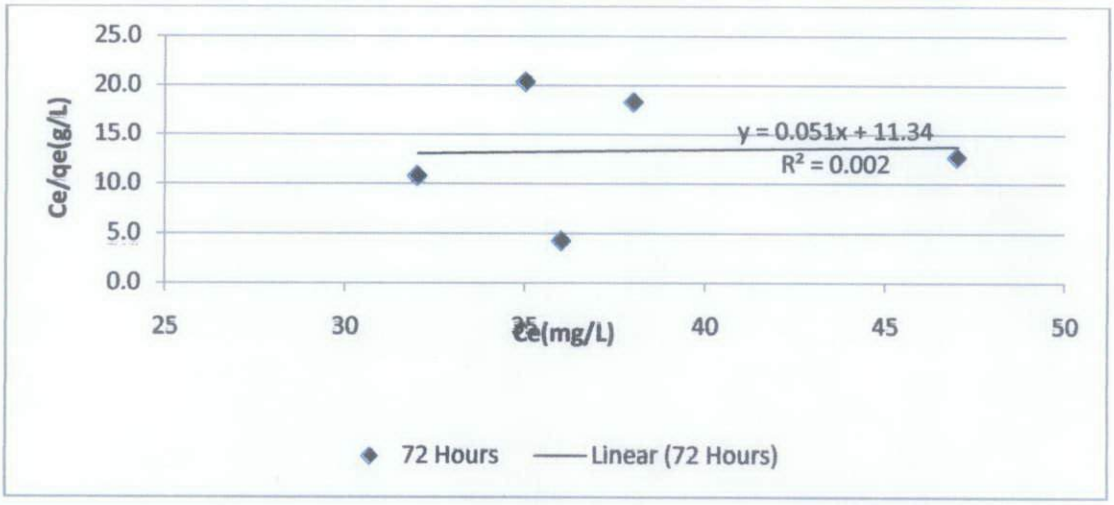


Figure 4.5c: Langmuir isotherm for Oil and Grease adsorption: [Oil grease 121 mg/l, contact time 72 h, volume 100 ml, agitation speed 250 rpm, temperature, 28±1 °C]

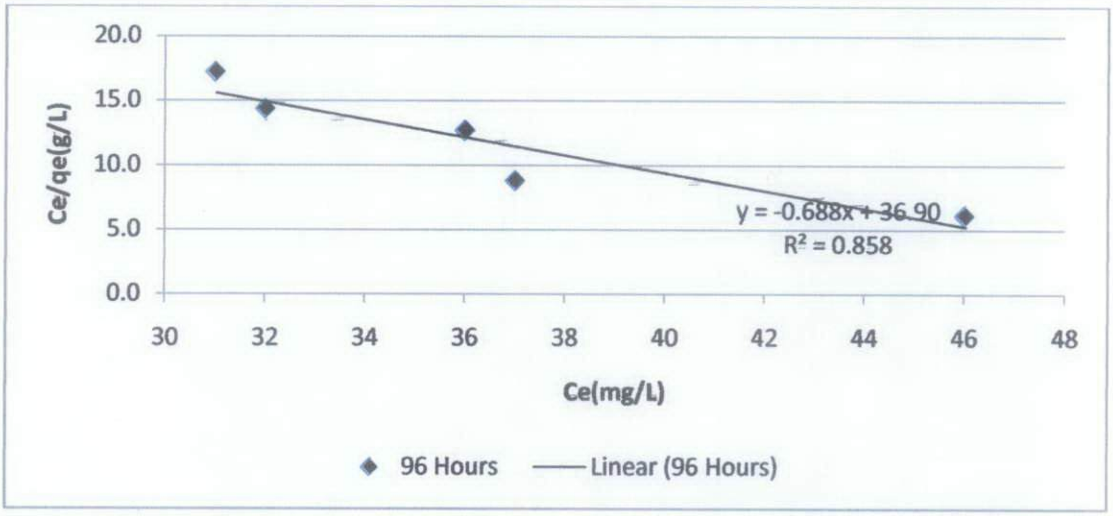


Figure 4.5d: Langmuir isotherm for Oil and Grease adsorption: [Oil grease 121 mg/l, contact time 96 h, volume 100 ml, agitation speed 250 rpm, temperature, 28±1 °C]

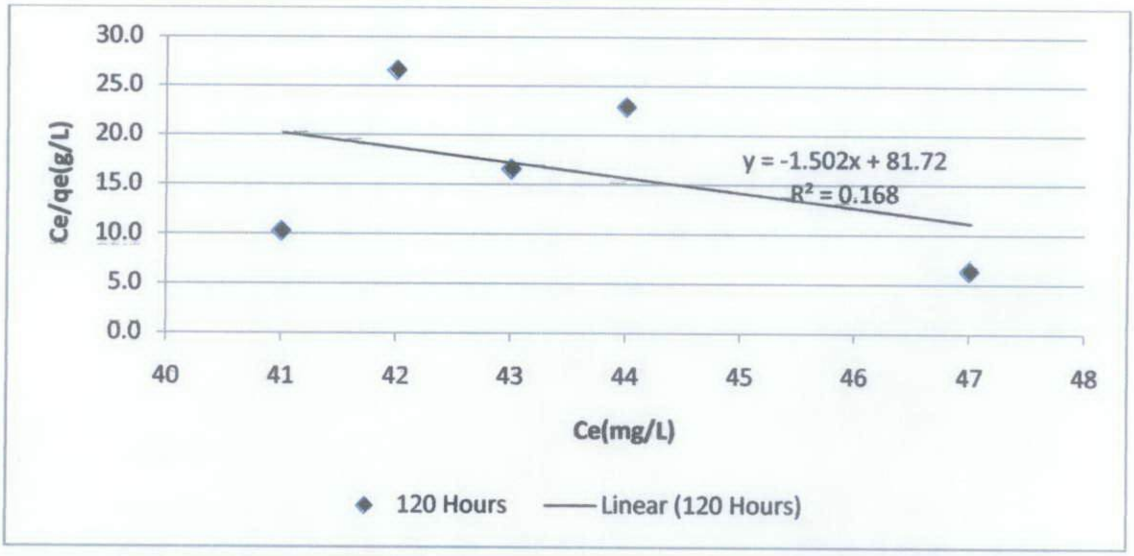


Figure 4.5e: Langmuir isotherm for Oil and Grease adsorption: [Oil grease 121 mg/l, contact time 120 h, volume 100 ml, agitation speed 250 rpm, temperature, 28±1 °C]

Following is Freundlich isotherms that have been plot from oil and grease concentration after treatment data. The data varies according to contact times that are 24 hours, 48 hours, 72 hours, 96 hours and 120 hours that reach equilibrium state.

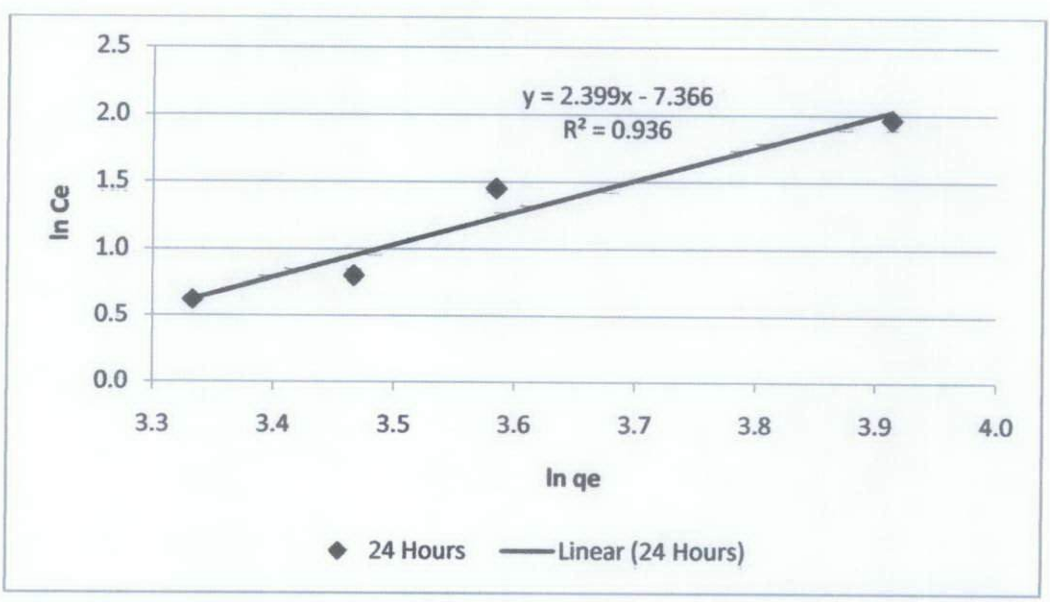


Figure 4.6a: Freundlich isotherm for Oil and Grease adsorption: [Oil grease 121 mg/l, contact time 24 h, volume 100 ml, agitation speed 250 rpm, temperature, 28±1 °C]

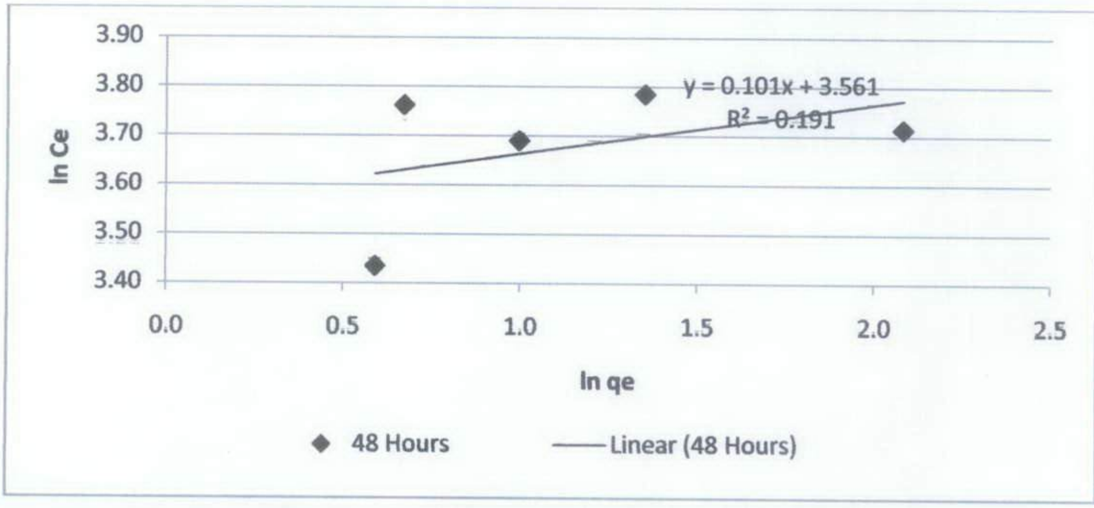


Figure 4.6b: Freundlich isotherm for Oil and Grease adsorption: [Oil grease 121 mg/l, contact time 48 h, volume 100 ml, agitation speed 250 rpm, temperature, 28±1 °C]

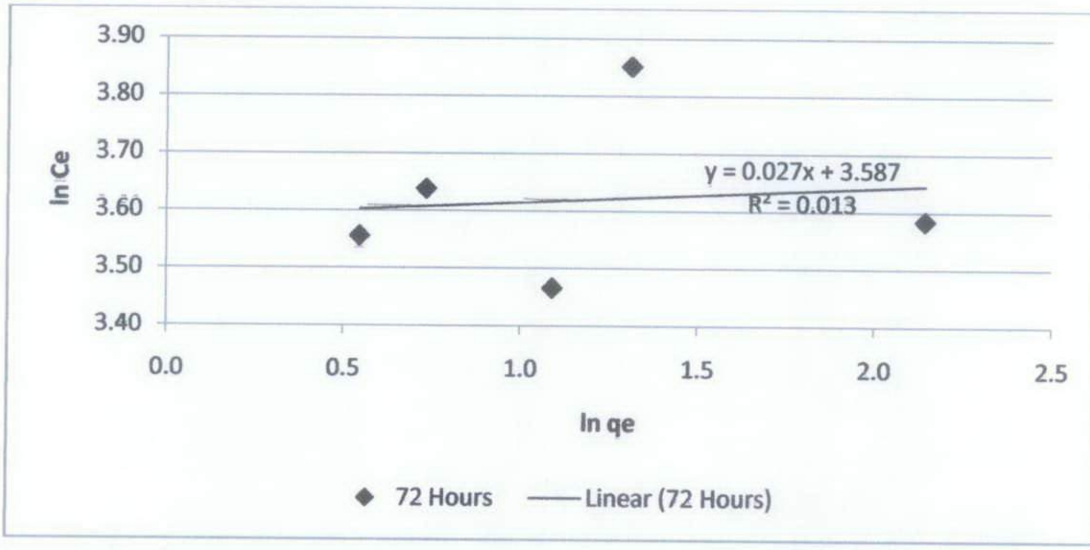


Figure 4.6c: Freundlich isotherm for Oil and Grease adsorption: [Oil grease 121 mg/l, contact time 72 h, volume 100 ml, agitation speed 250 rpm, temperature, 28±1 °C]

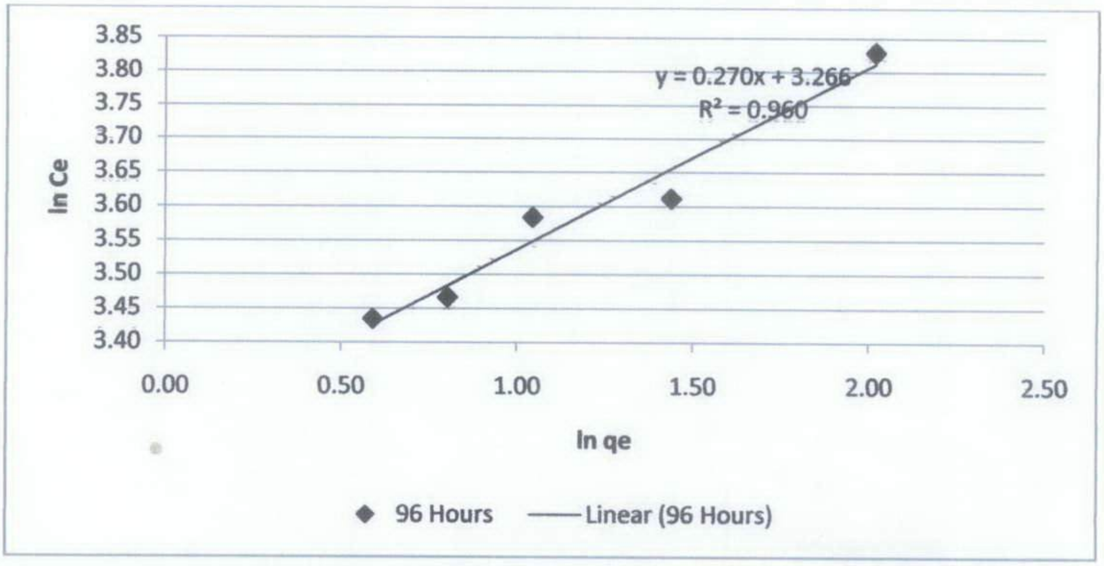


Figure 4.6d: Freundlich isotherm for Oil and Grease adsorption: [Oil grease 121 mg/l, contact time 96 h, volume 100 ml, agitation speed 250 rpm, temperature, 28±1 °C]

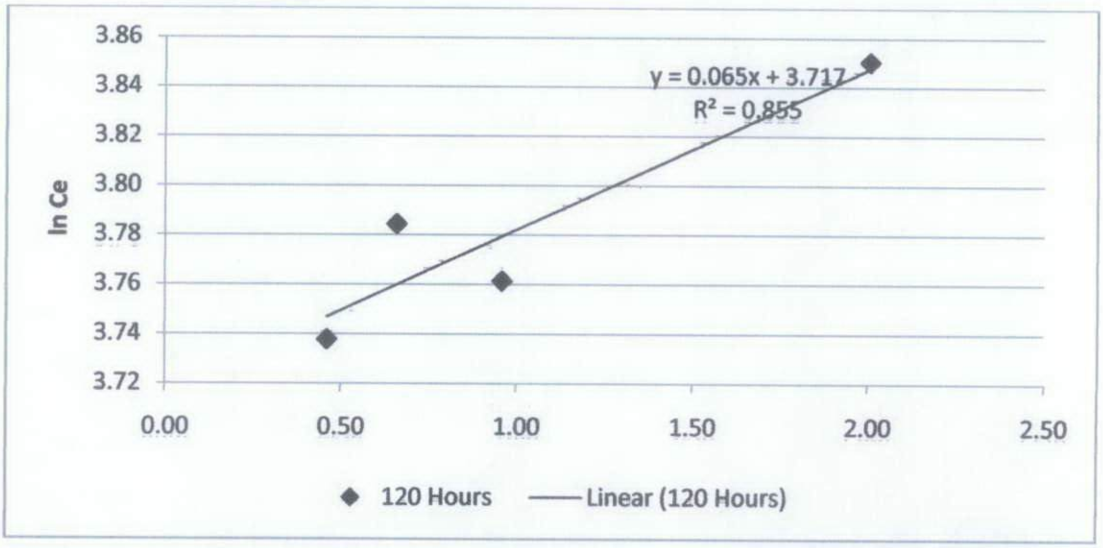


Figure 4.6e: Freundlich isotherm for Oil and Grease adsorption: [Oil grease 121 mg/l, contact time 120 h, volume 100 ml, agitation speed 250 rpm, temperature, 28±1 °C]

Table 4.1: Isotherm constants and correlation coefficients

	Langmuir isotherm coefficients			Freundlich isotherm coefficients		
24 Hours	Q_0	b	R^2	K_f	1/n	R^2
	-2.703	-0.0149	0.758	21.41	0.39	0.936

	Langmuir isotherm coefficients			Freundlich isotherm coefficients		
48 Hours	Q_0	b	R^2	K_f	1/n	R^2
	-4.48	-0.0097	0.033	35.2	0.101	0.191

	Langmuir isotherm coefficients			Freundlich isotherm coefficients		
72 Hours	Q_0	b	R^2	K_f	1/n	R^2
	19.6	0.0046	0.002	36.13	0.027	0.013

	Langmuir isotherm coefficients			Freundlich isotherm coefficients		
96 Hours	Q_0	b	R^2	K_f	1/n	R^2
	-1.45	-0.019	0.858	26.2	0.27	0.96

	Langmuir isotherm coefficients			Freundlich isotherm coefficients		
120 Hours	Q_0	b	R^2	K_f	1/n	R^2
	-0.67	-0.018	0.168	41.14	0.065	0.855

From **Figure 4.3** and **4.4,** the Langmuir and Freundlich isotherms are modelled by plotting a linear line. The Langmuir and Freundlich isotherm constants were found through the graph that has been plotted as shown in **Figure 4.5 and 4.6** and their values are shown in **Table 4.3.** It can be conclude that the Freundlich model is occupied in this oil and grease adsorption by HHW as the R^2 value is higher than R^2 value of Langmuir model. The Freundlich modeling comprehends the heterogeneity of the adsorbent's surface, their energies and exponential distribution sites (Isa et.al, 2008).

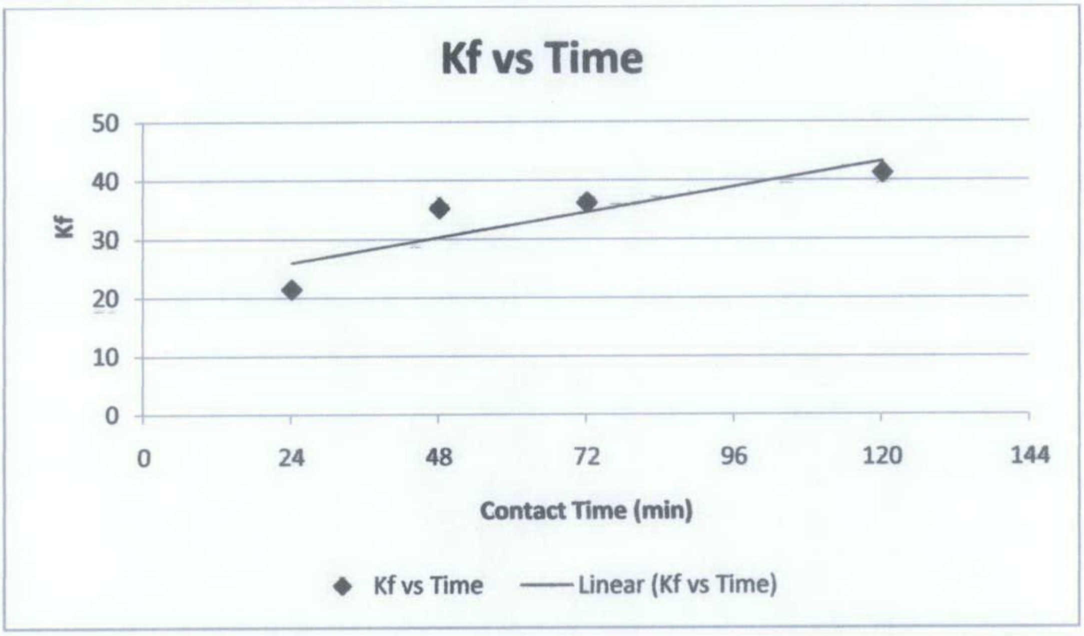


Figure 4.7: Kf value of Freundlich isotherm vs Time (Hours) for Oil and Grease adsorption

Figure 4.15, is plotted to see the relation between contact time and Kf value that represent adsorption capacity. As the contact time increased, the adsorption capacity also increased which means that oil and grease removal create time dependency process. Therefore, the required contact time is important for adsorption to be completed in a adsorption process.

4.1.2.4 Kinetics Studies

Figures below are the kinetics data that have been plot according to contact time reaction towards the adsorption of oil and grease by HHW.

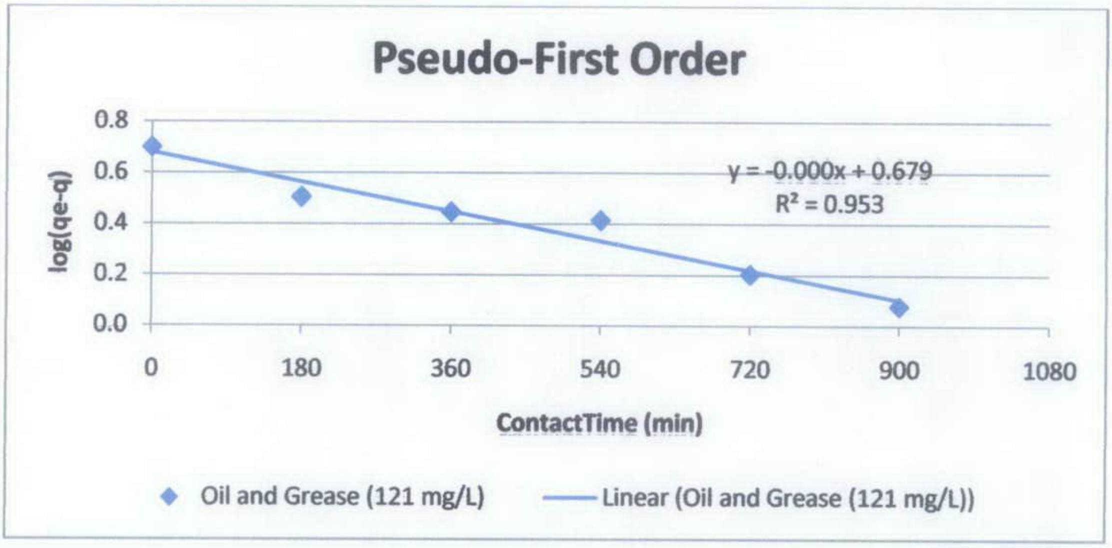


Figure 4.8: Pseudo first order kinetic plot for oil and grease adsorption with initial concentration of 121 mg/L [Volume 100ml, agitation speed 250 rpm, adsorbent dosage 50 000 mg/L, Temperature 28±1°C]

Table 4.2: Pseudo first order reaction rate for oil and grease adsorption

	Pseudo 1st Kinetic		
Oil & grease Conc.(mg/L)	k1(min^{-1})	R^2	Equation
121	0	0.953	y = -0.000x + 0.679

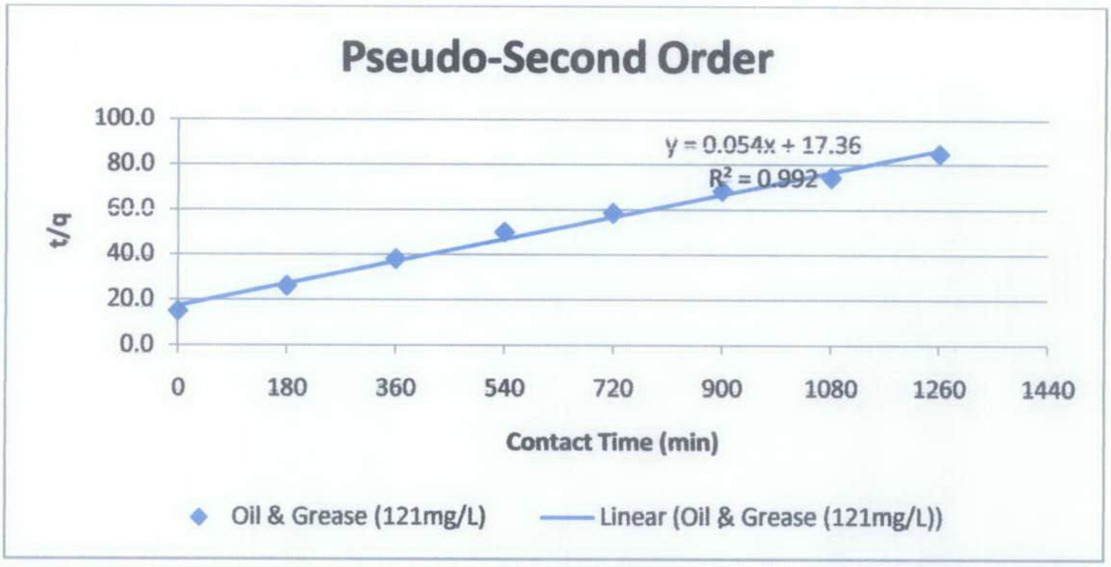


Figure 4.9: Pseudo second order kinetic plot for oil and grease adsorption with initial concentration of 121 mg/L [Volume 100ml, agitation speed 250 rpm, adsorbent dosage 50000mg/L, Temperature 28±1°C]

Table 4.3: Pseudo second order reaction rate for oil and grease adsorption

	Pseudo 2nd Kinetic		
Oil & grease Conc.(mg/L)	k2(min^{-1})	R^2	Equation
121	0.000168	0.992	y = 0.054x + 17.36

Figure 4.8 and **4.9** shows the kinetic models that are pseudo first and pseudo second order that has been employed in this study. The linear line is plotted and the constants are calculated from this plot is shown in **Table 4.4** and **4.5**. High R^2 values were obtained in both cases, showing good correlation of data for both models. But the R^2 of pseudo second order is higher than pseudo first order, therefore it can be conclude that the adsorption kinetics for oil and grease by HHW are better expressed by pseudo second order kinetic model. According to second order kinetic model, it is strongly support that chemisorption between the adsorbent and adsorbate (Isa et.al, 2008) which mean that the adsorbate is held on the surface of adsorbent by chemical bond.

4.1.3 SEM Test

SEM test was done to determine the differences in physical changes to HHW before and after the oil and grease removal.

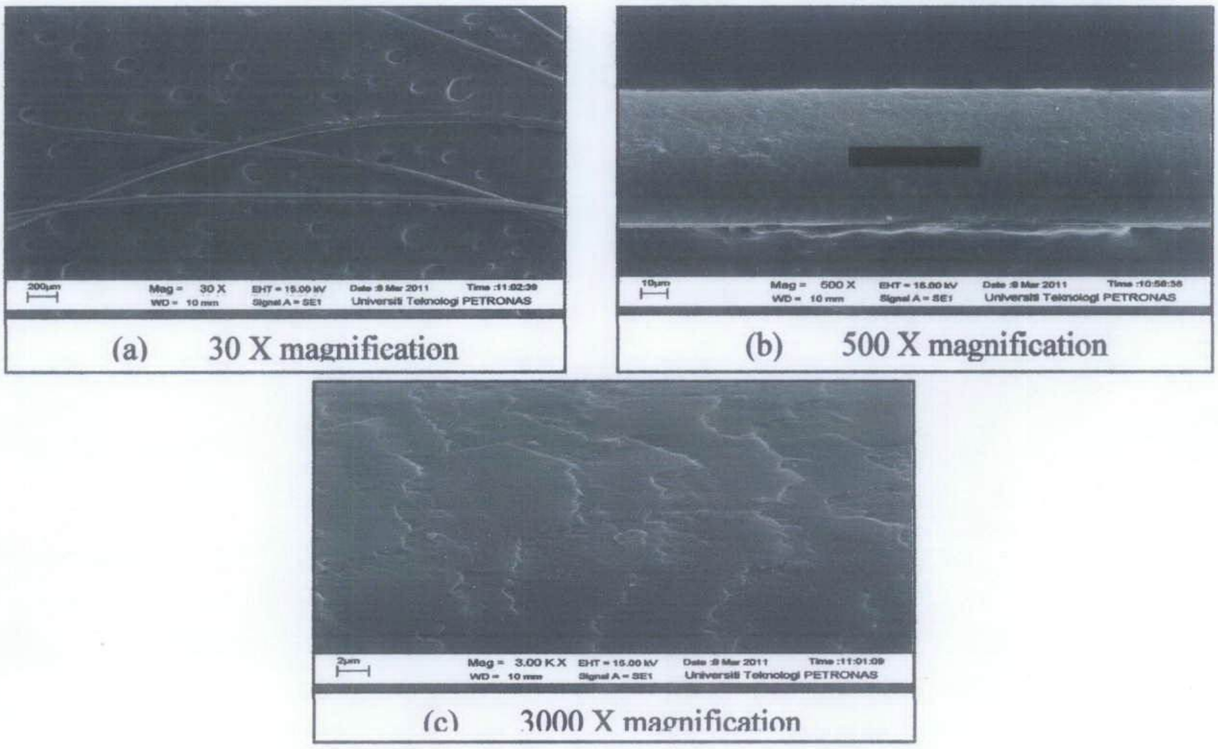


Figure 4.11: Hair structure before oil & grease removal treatment

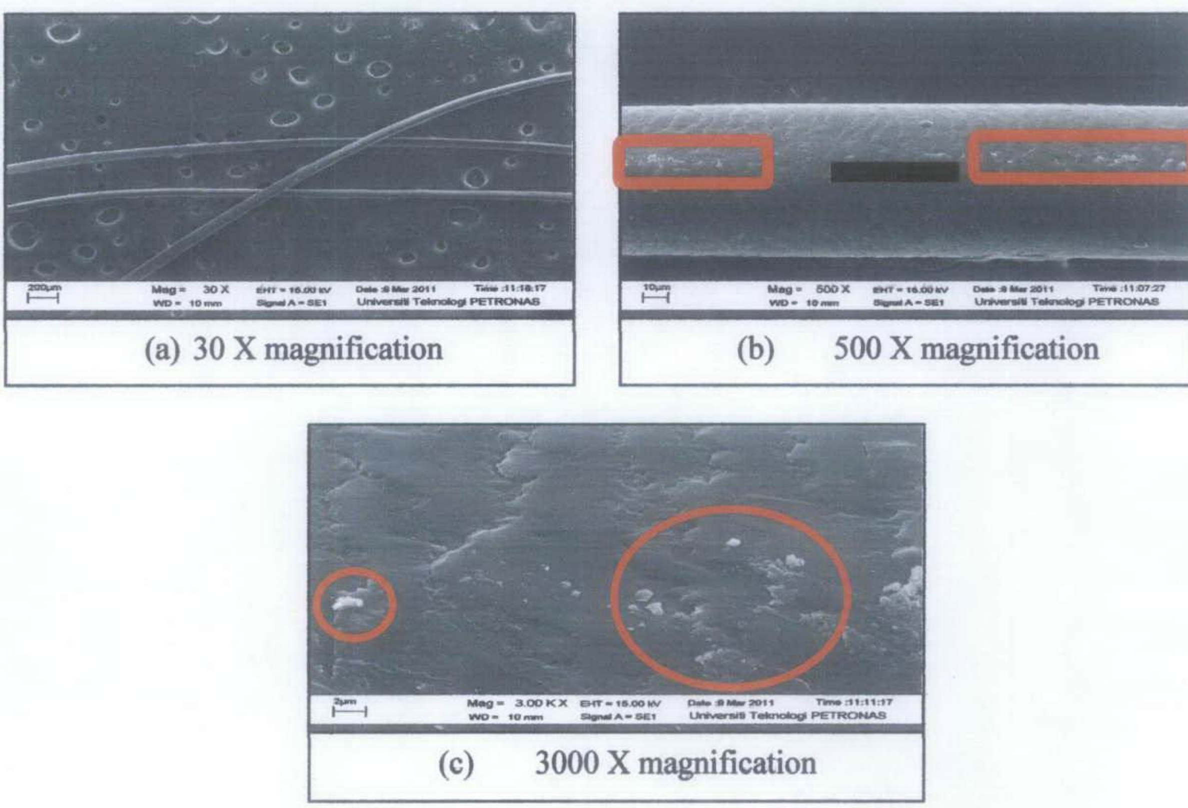


Figure 4.14: Hair structure after oil & grease removal treatment

Referring to SEM test result, it is obviously has the differences on the surface of the human hair waste between before and after the oil and grease removal process. By looking at the Figure 4.13 and 4.14 that has been marked with red circle/oval, it shows that there are some particles on the surface after the oil and grease removal process as it is expected as the oil and grease that being adsorb by the hair. In order to know the particles substance, X-Ray Fluorescence, XRF test need to be done.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Human hair waste (HHW) is available in abundance in Malaysia or any country as people go to cut their hair and it is just wasted without any use, was chosen for oil and grease removal from oil refinery wastewater. The idea also come from after hair is also used to remove or cleaned up oil spills at sea.

As a conclusion, results from batch experiments shows that HHW is feasible to remove oil and grease as it is removed by 78 % percentage removal with the 50 000 mg/L dosage of HHW and 24 hours contact time as it reached the equilibrium state but it is not feasible to use for industrial application as it takes too much hair and too long to remove small amount of oil and grease. The adsorption of oil and grease by HHW can be classified by Freundlich isotherms and pseudo second order kinetic model. The objective of this study is achieved that to determine the feasibility of Human Hair Waste (HHW) to remove oil and grease.

This project needs further study in order to improve the variation of data and to study efficiency of HHW as one of the oil and grease remover. The study like column study can be used to find the other parameters variation that can support HHW as oil and grease remover besides extending the variety of parameters like effect of temperature, pH, concentration of solution and so on because all these parameters may affect the oil and grease adsorption by HHW. Besides, it may need to check the physical structure and content of the hair before and after the oil and grease removal process by doing X-Ray Fluorescence, XRF in order to look at the properties of particle that may hold on the adsorbent surface.

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APPENDIX A

Malaysian Environmental Quality (Sewage and Industrial Effluents Regulations, 1979, 1999, 2000)

Malaysia Sewage and Industrial Effluent Discharge Standards

According to Malaysia's Environmental Law, ENVIRONMENTAL QUALITY ACT, 1974, the Malaysia Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979, 1999, 2000:

PARAMETER LIMITS OF EFFLUENT OF STANDARDS A AND B

Parameter	Unit	Standard A	B
-1	-2	-3	-4
(i) Temperature	°C	40	40
(ii) pH Value		6.0 - 9.0	5.5 - 9.0
(iii) BOD5 at 20°C	mg/l	20	50
(iv) COD	mg/l	50	100
(v) Suspended Solids	mg/l	50	100
(vi) Mercury	mg/l	0.005	0.05
(vii) Cadmium	mg/l	0.01	0.02
(viii) Chromium, Hexavalent	mg/l	0.05	0.05
(ix) Arsenic	mg/l	0.05	0.1
(x) Cyanide	mg/l	0.05	0.1
(xi) Lead	mg/l	0.1	0.5
(xii) Chormium, Trivalent	mg/l	0.2	1
(xiii) Copper	mg/l	0.2	1
(xiv) Manganese	mg/l	0.2	1
(xv) Nickel	mg/l	0.2	1
(xvi) Tin	mg/l	0.2	1
(xvii) Zinc	mg/l	1	1
(xviii) Boron	mg/l	1	4
(xix) Iron (Fe)	mg/l	1	5
(xx) Phenol	mg/l	0.001	1
(xxi) Free Chlorine	mg/l	1	2
(xxii) Sulphide	mg/l	0.5	0.5
(xxiii) Oil and Grease	mg/l	Not detectable	10

APPENDIX B

Gantt chart for Final Year Project 2

No.	Detail/Week	1	2	3	4	5	6	7	8	9	10		11	12	13	14
1	Finalize the method of experiment of	■	■	■												
2	Finalize the material to be use		■	■												
3	Run the experiment (Column study)			■	■	■	■	■								
4	Run the SEM & XRD test							■	■	■	■		■			
5	Progress report 1 preparation		■	■												
6	Submission of progress report 1				●											
7	Progress report 2 preparation						■	■								
8	Progress report 2 submission								●							
9	Seminar preparation								■	■						
10	Seminar										●					
11	Poster exhibition preparation								■	■						
12	Poster exhibition										●					
13	Dissertation preparation										■		■			
14	Submission of dissertation (soft copy)													●		
15	Oral presentation preparation												■	■		
16	Oral presentation														●	
17	Submission of Project Dissertation (hard bound)															●

■ Process

● Suggested milestone

APPENDIX C

Oil & Grease removal Test Result

Oil & Grease Concentration after Treatment

	Oil & Grease Concentration (mg/L)								
Dosage(mg/L)/time(hour)	0	3	6	9	12	15	18	21	24
0	121	120	121	121	120	120	120	121	120
10000	121	100	98	101	97	83	75	71	50
20000	121	95	91	93	84	75	66	60	36
30000	121	82	86	75	74	72	54	48	26
40000	121	65	61	72	70	55	45	38	32
50000	121	61	52	50	49	44	42	36	36

*Volume 100ml, contact time various with 3 hours interval, agitation speed 250 rpm, Adsorbent dosage varies from 10000 mg/L to 50000 mg/L, temperature 28± 1° C.

Oil & Grease Percentage Removal

	Oil & Grease Percentage Removal (%)								
Dosage(mg/L)/time(hour)	0	3	6	9	12	15	18	21	24
0									
10000	0	16.7	19.0	16.5	19.2	30.8	37.5	41.3	58.3
20000	0	20.8	24.8	23.1	30.0	37.5	45.0	50.4	70.0
30000	0	31.7	28.9	38.0	38.3	40.0	55.0	60.3	78.3
40000	0	45.8	49.6	40.5	41.7	54.2	62.5	68.6	73.3
50000	0	49.2	57.0	58.7	59.2	63.3	65.0	70.2	70.0

Oil & Grease Concentration after Treatment (extended hours)

Weight(mg)/time(hour)	Oil & Grease Concentration (mg/L)					
	0	24	48	72	96	120
0	121	120	120	121	121	121
10000	121	50	41	36	46	47
20000	121	36	44	47	37	41
30000	121	30	40	32	36	43
40000	121	32	43	38	32	44
50000	121	36	31	35	31	42

*Volume 100ml, contact time various with 24 hours interval, agitation speed 250 rpm, Adsorbent dosage varies from 10000 mg/L to 50000 mg/L, temperature 28± 1° C.

APPENDIX D

T-Statistic Data Analysis

T-Stat for Contact time with P>95% (α= 5%)

t-Test: Two-Sample Assuming Equal Variances

3 hours & 6 hours

	Variable 1	*Variable 2*
Mean	87.16667	84.83333
Variance	501.3667	633.3667
Observations	6	6
Pooled Variance	567.3667	
Hypothesized Mean Difference	0	
df	10	
t Stat	0.16967	
P(T<=t) one-tail	0.434326	
t Critical one-tail	1.812461	
P(T<=t) two-tail	0.868653	
t Critical two-tail	2.228139	

Since t stat is in between -2.22 & 2.22, Ho is true means that there is no significance difference between 3 hours and 6 hours.

t-Test: Two-Sample Assuming Equal Variances

3 hours & 9 hours

	Variable 1	*Variable 2*
Mean	87.16667	85.33333
Variance	501.3667	621.8667
Observations	6	6
Pooled Variance	561.6167	
Hypothesized Mean Difference	0	
df	10	
t Stat	0.133993	
P(T<=t) one-tail	0.448033	
t Critical one-tail	1.812461	
P(T<=t) two-tail	0.896066	
t Critical two-tail	2.228139	

Since t stat is in between -2.22 & 2.22, Ho is true means that there is no significance difference between 3 hours and 9 hours.

t-Test: Two-Sample Assuming Equal Variances

3 hours & 12 hours

	Variable 1	*Variable 2*
Mean	87.16666667	82.33333
Variance	501.3666667	593.8667
Observations	6	6
Pooled Variance	547.6166667	
Hypothesized Mean Difference	0	
df	10	
t Stat	0.357741271	
P(T<=t) one-tail	0.363986212	
t Critical one-tail	1.812461102	
P(T<=t) two-tail	0.727972424	
t Critical two-tail	2.228138842	

Since t stat is in between -2.22 & 2.22, Ho is true means that there is no significance difference between 3 hours and 12 hours.

t-Test: Two-Sample Assuming Equal Variances

3 hours & 15 hours

	Variable 1	*Variable 2*
Mean	87.16667	74.83333
Variance	501.3667	691.7667
Observations	6	6
Pooled Variance	596.5667	
Hypothesized Mean Difference	0	
df	10	
t Stat	0.874604	
P(T<=t) one-tail	0.201153	
t Critical one-tail	1.812461	
P(T<=t) two-tail	0.402306	
t Critical two-tail	2.228139	

Since t stat is in between -2.22 & 2.22, Ho is true means that there is no significance difference between 3 hours and 15 hours.

t-Test: Two-Sample Assuming Equal Variances

3 hours & 18 hours

	Variable 1	*Variable 2*
Mean	87.16667	67
Variance	501.3667	830.4
Observations	6	6
Pooled Variance	665.8833	
Hypothesized Mean Difference	0	
df	10	
t Stat	1.353617	
P(T<=t) one-tail	0.10283	
t Critical one-tail	1.812461	
P(T<=t) two-tail	0.205661	
t Critical two-tail	2.228139	

Since t stat is in between -2.22 & 2.22, Ho is true means that there is no significance difference between 3 hours and 18 hours.

t-Test: Two-Sample Assuming Equal Variances

3 hours & 21 hours

	Variable 1	*Variable 2*
Mean	87.16667	62.33333
Variance	501.3667	1002.667
Observations	6	6
Pooled Variance	752.0167	
Hypothesized Mean Difference	0	
df	10	
t Stat	1.568491	
P(T<=t) one-tail	0.073919	
t Critical one-tail	1.812461	
P(T<=t) two-tail	0.147838	
t Critical two-tail	2.228139	

Since t stat is in between -2.22 & 2.22, Ho is true means that there is no significance difference between 3 hours and 21 hours.

t-Test: Two-Sample Assuming Equal Variances

3 hours & 24 hours

	Variable 1	*Variable 2*
Mean	87.16667	50
Variance	501.3667	1238.4
Observations	6	6
Pooled Variance	869.8833	
Hypothesized Mean Difference	0	
df	10	
t Stat	2.182648	
P(T<=t) one-tail	0.027002	
t Critical one-tail	1.812461	
P(T<=t) two-tail	0.054003	
t Critical two-tail	2.228139	

Since t stat is in between -2.22 & 2.22, Ho is true means that there is no significance difference between 3 hours and 24 hours.

T-Stat for Contact time with P>90% (α= 10%)

t-Test: Two-Sample Assuming Equal Variances

3 hours & 6 hours

	Variable 1	*Variable 2*
Mean	87.16667	84.83333
Variance	501.3667	633.3667
Observations	6	6
Pooled Variance	567.3667	
Hypothesized Mean Difference	0	
df	10	
t Stat	0.16967	
P(T<=t) one-tail	0.434326	
t Critical one-tail	1.372184	
P(T<=t) two-tail	0.868653	
t Critical two-tail	1.812461	

Since t stat is in between -1.81 & 1.81, Ho is true means that there is no significance difference between 3 hours and 6 hours

t-Test: Two-Sample Assuming Equal Variances

3 hours & 9 hours

	Variable 1	*Variable 2*
Mean	87.16667	85.33333
Variance	501.3667	621.8667
Observations	6	6
Pooled Variance	561.6167	
Hypothesized Mean Difference	0	
df	10	
t Stat	0.133993	
P(T<=t) one-tail	0.448033	
t Critical one-tail	1.372184	
P(T<=t) two-tail	0.896066	
t Critical two-tail	1.812461	

Since t stat is in between -1.81 & 1.81, Ho is true means that there is no significance difference between 3 hours and 9 hours.

t-Test: Two-Sample Assuming Equal Variances

3 hours & 12 hours

	Variable 1	*Variable 2*
Mean	87.16667	82.33333
Variance	501.3667	593.8667
Observations	6	6
Pooled Variance	547.6167	
Hypothesized Mean Difference	0	
df	10	
t Stat	0.357741	
P(T<=t) one-tail	0.363986	
t Critical one-tail	1.372184	
P(T<=t) two-tail	0.727972	
t Critical two-tail	1.812461	

Since t stat is in between -1.81 & 1.81, Ho is true means that there is no significance difference between 3 hours and 12 hours.

t-Test: Two-Sample Assuming Equal Variances

3 hours & 15 hours

	Variable 1	*Variable 2*
Mean	87.16667	74.83333
Variance	501.3667	691.7667
Observations	6	6
Pooled Variance	596.5667	
Hypothesized Mean Difference	0	
df	10	
t Stat	0.874604	
P(T<=t) one-tail	0.201153	
t Critical one-tail	1.372184	
P(T<=t) two-tail	0.402306	
t Critical two-tail	1.812461	

Since t stat is in between -1.81 & 1.81, Ho is true means that there is no significance difference between 3 hours and 15 hours.

t-Test: Two-Sample Assuming Equal Variances

3 hours & 18 hours

	Variable 1	*Variable 2*
Mean	87.16667	67
Variance	501.3667	830.4
Observations	6	6
Pooled Variance	665.8833	
Hypothesized Mean Difference	0	
df	10	
t Stat	1.353617	
P(T<=t) one-tail	0.10283	
t Critical one-tail	1.372184	
P(T<=t) two-tail	0.205661	
t Critical two-tail	1.812461	

Since t stat is in between -1.81 & 1.81, Ho is true means that there is no significance difference between 3 hours and 18 hours

t-Test: Two-Sample Assuming Equal Variances

3 hours & 21 hours

	Variable 1	*Variable 2*
Mean	87.16667	62.33333
Variance	501.3667	1002.667
Observations	6	6
Pooled Variance	752.0167	
Hypothesized Mean Difference	0	
df	10	
t Stat	1.568491	
P(T<=t) one-tail	0.073919	
t Critical one-tail	1.372184	
P(T<=t) two-tail	0.147838	
t Critical two-tail	1.812461	

Since t stat is in between -1.81 & 1.81, Ho is true means that there is no significance difference between 3 hours and 21 hours.

t-Test: Two-Sample Assuming Equal Variances

3 hours & 24 hours

	Variable 1	*Variable 2*
Mean	87.16667	50
Variance	501.3667	1238.4
Observations	6	6
Pooled Variance	869.8833	
Hypothesized Mean Difference	0	
df	10	
t Stat	2.182648	
P(T<=t) one-tail	0.027002	
t Critical one-tail	1.372184	
P(T<=t) two-tail	0.054003	
t Critical two-tail	1.812461	

Since t stat is not between -1.81 & 1.81, Ho is false mean that there is significance difference between 3 hours and 24 hours.

t-Test: Two-Sample Assuming Equal Variances

24 hours & 48 hours

	Variable 1	Variable 2
Mean	44	41
Variance	30.5	21.5
Observations	5	5
Pooled Variance	26	
Hypothesized Mean Difference	0	
df	8	
t Stat	0.930261	
P(T<=t) one-tail	0.189726	
t Critical one-tail	1.859548	
P(T<=t) two-tail	0.379452	
t Critical two-tail	2.306004	

Since t stat is between 2.3 & -2.3, Ho is true mean that there is no significance difference between 24 hours and 48 hours.

t-Test: Two-Sample Assuming Equal Variances

24 hours & 72 hours

	Variable 1	Variable 2
Mean	44	36.2
Variance	30.5	29.2
Observations	5	5
Pooled Variance	29.85	
Hypothesized Mean Difference	0	
df	8	
t Stat	2.257316	
P(T<=t) one-tail	0.026974	
t Critical one-tail	1.859548	
P(T<=t) two-tail	0.053948	
t Critical two-tail	2.306004	

Since t stat is between 2.3 & -2.3, Ho is true mean that there is no significance difference between 24 hours and 72 hours.

t-Test: Two-Sample Assuming Equal Variances

24 hours & 96 hours

	Variable 1	*Variable 2*
Mean	44	37.8
Variance	30.5	33.2
Observations	5	5
Pooled Variance	31.85	
Hypothesized Mean Difference	0	
df	8	
t Stat	1.737029	
P(T<=t) one-tail	0.060294	
t Critical one-tail	1.859548	
P(T<=t) two-tail	0.120588	
t Critical two-tail	2.306004	

Since t stat is between 2.3 & -2.3, Ho is true mean that there is no significance difference between 24 hours and 96 hours.

t-Test: Two-Sample Assuming Equal Variances

24 hours & 120 hours

	Variable 1	*Variable 2*
Mean	44	35
Variance	30.5	20.5
Observations	5	5
Pooled Variance	25.5	
Hypothesized Mean Difference	0	
df	8	
t Stat	2.818009	
P(T<=t) one-tail	0.011281	
t Critical one-tail	1.859548	
P(T<=t) two-tail	0.022563	
t Critical two-tail	2.306004	

Since t-stat is not fall between the t-critical value, Ho is false which means there is significance difference between 24 hours with 120 hours

T-Stat for HHW Dosages with P>95% (α= 5%)

t-Test: Two-Sample Assuming Equal Variances

10 000 mg/l & 20 000 mg/l

	Variable 1	*Variable 2*
Mean	84.375	75
Variance	330.8393	412.5714
Observations	8	8
Pooled Variance	371.7054	
Hypothesized Mean Difference	0	
df	14	
t Stat	0.972527	
P(T<=t) one-tail	0.173646	
t Critical one-tail	1.76131	
P(T<=t) two-tail	0.347293	
t Critical two-tail	2.144787	

Since t-stat is fall between the t-critical value, Ho is acceptable which means there is no significance difference between 10000 mg/l with 20000mg/l

t-Test: Two-Sample Assuming Equal Variances

10 000 mg/l & 30 000 mg/l

	Variable 1	*Variable 2*
Mean	84.375	64.625
Variance	330.8393	412.8393
Observations	8	8
Pooled Variance	371.8393	
Hypothesized Mean Difference	0	
df	14	
t Stat	2.048422	
P(T<=t) one-tail	0.029876	
t Critical one-tail	1.76131	
P(T<=t) two-tail	0.059752	
t Critical two-tail	2.144787	

Since t-stat is fall between the t-critical value, Ho is acceptable which means there is no significance difference between 10000 mg/l with 30000mg/l

t-Test: Two-Sample Assuming Equal Variances

10 000 mg/l & 40 000 mg/l

	Variable 1	*Variable 2*
Mean	84.375	54.75
Variance	330.8393	223.9286
Observations	8	8
Pooled Variance	277.3839	
Hypothesized Mean Difference	0	
df	14	
t Stat	3.557523	
P(T<=t) one-tail	0.001577	
t Critical one-tail	1.76131	
P(T<=t) two-tail	0.003153	
t Critical two-tail	2.144787	

Since t-stat is not fall between the t-critical value, Ho is false which means there is significance difference between 10000 mg/l with 40000mg/l

t-Test: Two-Sample Assuming Equal Variances

10 000 mg/l & 50 000 mg/l

	Variable 1	*Variable 2*
Mean	84.375	45.25
Variance	330.8393	103.6429
Observations	8	8
Pooled Variance	217.2411	
Hypothesized Mean Difference	0	
df	14	
t Stat	5.309008	
P(T<=t) one-tail	5.52E-05	
t Critical one-tail	1.76131	
P(T<=t) two-tail	0.00011	
t Critical two-tail	2.144787	

Since t-stat is not fall between the t-critical value, Ho is false which means there is significance difference between 10000 mg/l with 50000mg/l

APPENDIX D

Isotherms and Kinetic Studies Data Analysis

Isotherms Studies Data Analysis

langmuir

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24 hours

m (g)	Co (mg/L)	Ce (mg/L)	Removal (%)	x=Co-Ce (mg)	qe=x/m (mg/g)	ln Ce	ln qe	Ce/qe (g/L)	log qe	log ce
0	121.00	120	0.83	0.10						2.079181
1	121.00	50	57.85	7.10	7.10	3.9120	1.9601	7.0423	0.851258	1.69897
2	121.00	36	69.42	8.50	4.25	3.5835	1.4469	8.4706	0.628389	1.556303
3	121.00	30	74.38	9.10	3.03		1.1097		0.48192	1.477121
4	121.00	32	72.73	8.90	2.23	3.4657	0.7998	14.3820	0.34733	1.50515
5	121.00	28	76.03	9.30	1.86	3.3322	0.6206	15.0538	0.269513	1.447158

48 hours

m (g)	Co (mg/L)	Ce (mg/L)	Removal (%)	x=Co-Ce (mg)	qe=x/m (mg/g)	ln Ce	ln qe	Ce/qe (g/L)	log qe	log ce
0	121.00	120	0.83	0.10						2.079181
1	121.00	41	65.29	8.00	8.00	3.7136	2.0794	5.1250	0.90309	1.612784
2	121.00	44	62.81	7.70	3.85	3.7842	1.3481	11.4286	0.585461	1.643453
3	121.00	40	66.12	8.10	2.70	3.6889	0.9933	14.8148	0.431364	1.60206
4	121.00	43	63.64	7.80	1.95	3.7612	0.6678	22.0513	0.290035	1.633468
5	121.00	31	73.55	9.00	1.80	3.4340	0.5878	17.2222	0.255273	1.491362

72 hours

m (g)	Co (mg/L)	Ce (mg/L)	Removal (%)	x=Co-Ce (mg)	qe=x/m (mg/g)	ln Ce	ln qe	Ce/qe (g/L)	log qe	log ce
0	121.00	121	0.00	0.00						2.082785
1	121.00	36	70.25	8.50	8.50	3.5835	2.1401	4.2353	0.929419	1.556303
2	121.00	47	61.16	7.40	3.70	3.8501	1.3083	12.7027	0.568202	1.672098
3	121.00	32	73.55	8.90	2.97	3.4657	1.0874	10.7865	0.472269	1.50515
4	121.00	38	68.60	8.30	2.08	3.6376	0.7300	18.3133	0.317018	1.579784
5	121.00	35	71.07	8.60	1.72	3.5553	0.5423	20.3488	0.235528	1.544068

96 hours

m (g)	Co (mg/L)	Ce (mg/L)	Removal (%)	x=Co-Ce (mg)	qe=x/m (mg/g)	ln Ce	ln qe	Ce/qe (g/L)	log qe	log ce
0	121.00	121	0.00	0.00						2.082785
1	121.00	46	61.98	7.50	7.50	3.8286	2.0149	6.1333	0.875061	1.662758
2	121.00	37	69.42	8.40	4.20	3.6109	1.4351	8.8095	0.623249	1.568202
3	121.00	36	70.25	8.50	2.83	3.5835	1.0415	12.7059	0.452298	1.556303
4	121.00	32	73.55	8.90	2.23	3.4657	0.7998	14.3820	0.34733	1.50515
5	121.00	31	74.38	9.00	1.80	3.4340	0.5878	17.2222	0.255273	1.491362

120 hours

m (g)	Co (mg/L)	Ce (mg/L)	Removal (%)	x=Co-Ce (mg)	qe=x/m (mg/g)	ln Ce	ln qe	Ce/qe (g/L)	log qe	log ce
0	121.00	121	0.00	0.00						2.082785
1	121.00	47	61.16	7.40	7.40	3.8501	2.0015	6.3514	0.869232	1.672098
2	121.00	41	66.12	8.00	4.00			10.2500	0.60206	1.612784
3	121.00	43	64.46	7.80	2.60	3.7612	0.9555	16.5385	0.414973	1.633468
4	121.00	44	63.64	7.70	1.93	3.7842	0.6549	22.8571	0.284431	1.643453
5	121.00	42	65.29	7.90	1.58	3.7377	0.4574	26.5823	0.198657	1.623249

Kinetics Studies Data Analysis

For 50000mg/L

Contact time (min)	Co (mg/L)	Ce (mg/L)	q	qe	t/q	qe-q	log (qe-q)
0	121.00	121.00	0	17.00			
180	121.00	61.00	12.00	17.00	15.0000	5.00	0.6990
360	121.00	52.00	13.80	17.00	26.0870	3.20	0.5051
540	121.00	50.00	14.20	17.00	38.0282	2.80	0.4472
720	121.00	49.00	14.40	17.00	50.0000	2.60	0.4150
900	121.00	44.00	15.40	17.00	58.4416	1.60	0.2041
1080	121.00	42.00	15.80	17.00	68.3544	1.20	0.0792
1260	121.00	36.00	17.00	17.00	74.1176	0.00	
1440	121.00	36.00	17.00	17.00	84.7059	0.00	